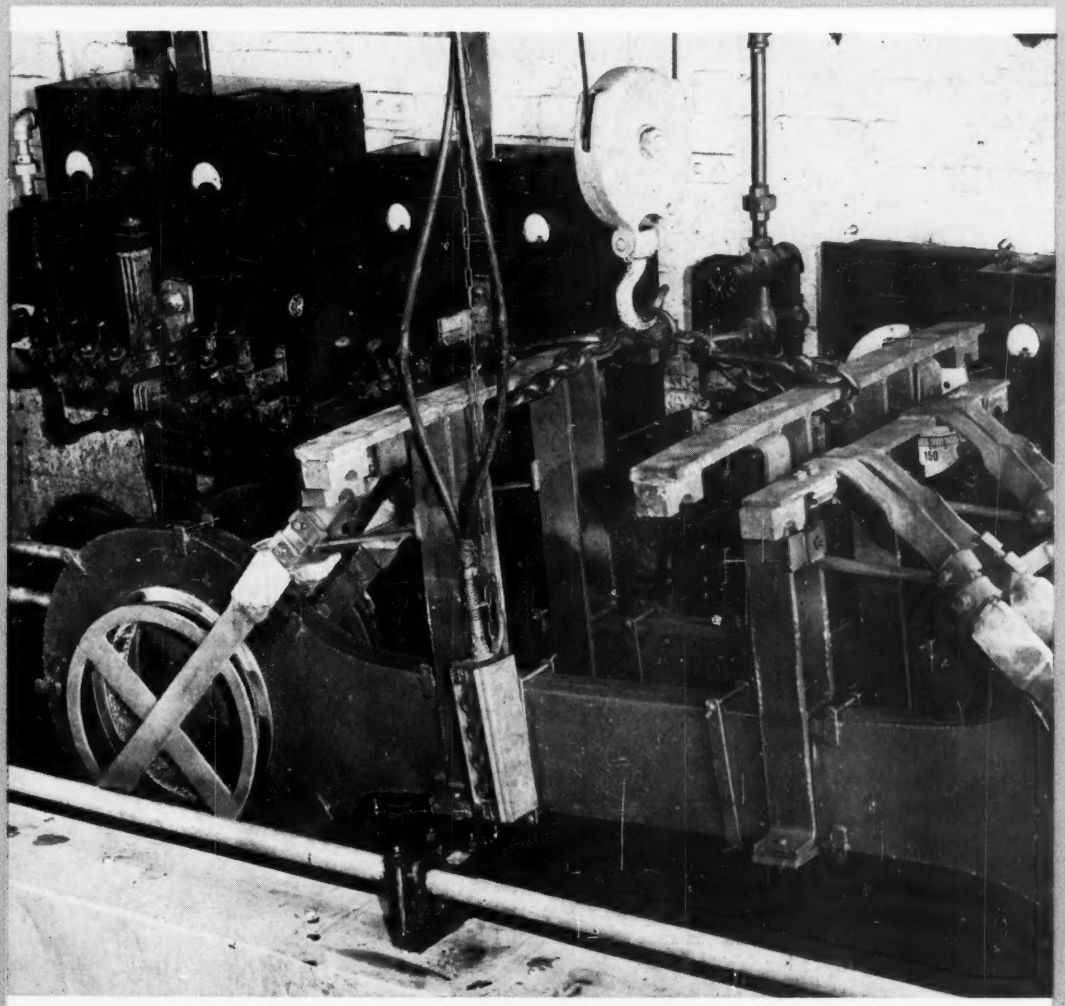
Vol. 15, No. 1 January, 1959

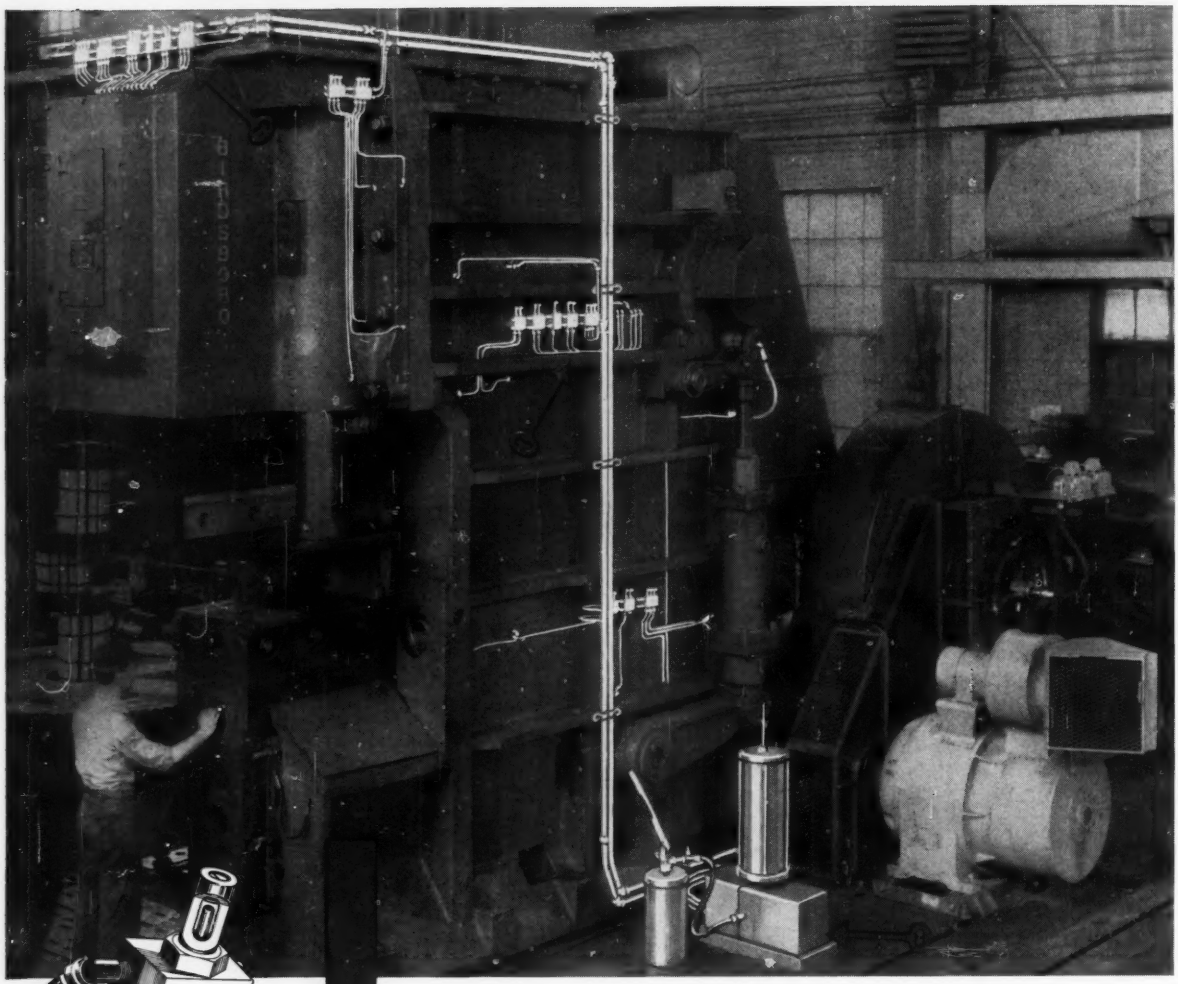
LUBRICATION ENGINEERING

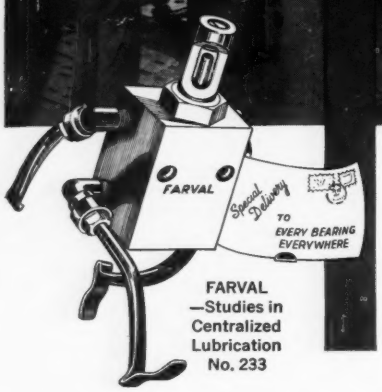
DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE



Hard-chrome plating renews locomotive drive-rod bearing surfaces

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS





FARVAL
—Studies in
Centralized
Lubrication
No. 233

Farval automatically lubricates 61 bearings on this Birdsboro Shear at Sharon Steel Corporation

This giant 1000-ton Birdsboro hot bloom and slab shear—largest of its type—completes a cut in only 4½ seconds. Actual cutting is done by the rising action of the up-and-down cut shear's bottom knife—gives square-cut ends free from hook.

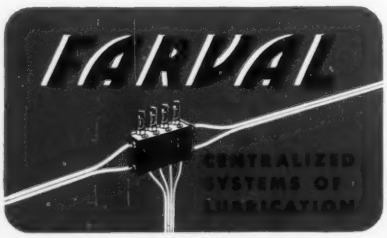
Keeping this heavy-duty cycle machine in production around-the-clock requires continuous, positive lubrication. So a modern motor-driven Farval system was installed. It's time clock controlled to eliminate the human element—makes sure the shear's 61 bearings are never without proper lubrication.

Remember, for the ultimate in bearing protection on any of your production machines—it's Farval. For the latest information on what Farval can do in your plant, write for free Bulletin 26-S. The Farval Corporation, 3267 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

KEYS TO ADEQUATE LUBRICATION

Wherever you see the sign of Farval —familiar valve manifolds, dual lubricant lines and central pumping station—you know a machine is being properly lubricated.



Volume 15, No. 1
January, 1959

Lubrication Engineering

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

Contents

LUBRICATION IN PRACTICE

Economics of Rolling-Contact Bearing Inspection .....C. L. Miller 18

Lubrication Problems in High-Speed Gears .....J. Dern 23

DESIGN, RESEARCH, DEVELOPMENT

The Causes and the Control of Electrical Current in Bearings .....J. Boyd and H. N. Kaufman 28

CURRENT NEWS

Lubrication in the News 2, 4

FEATURES

Editorial 17

Lube Lines 15

Book Review 14

News Notebook 10

TRADE INFORMATION

Advertisers' Index 40

New Products 6, 8

LITERATURE SUMMARIZED

Lubrication Abstracts 39

Patent Abstracts 37

Cover photo courtesy Norfolk & Western R. R. Co.

John Boyd, Editor
Vera Blake, Production Editor
A. F. Brewer, Consulting Editor
C. L. Willey, Business Manager

ASLE Publications Committee

D. W. Sawyer, ALCOA Research Laboratories, Chairman
John Boyd, Westinghouse Research Laboratories
J. Willard Peterson, Standard Oil Co. (Indiana)
C. A. Tomczak
C. L. Willey

Editorial Review Committee

John Boyd, Chairman
W. E. Campbell, Consulting Chemist
R. K. Gould, Beacon Laboratories, Texas Co.
A. A. Raimondi, Westinghouse Research Laboratories
E. E. Bisson, NASA
John Givens, Shell Oil Co.
Ernest Rabinowicz, MIT
M. C. Shaw, MIT
L. B. Sargent, Jr., ALCOA Research Labs.
H. W. McCulloch, Jr., Shell Oil Co.
L. E. Hoyer, American Brake Shoe Co.
A. F. Brewer, Consultant
D. Godfrey, California Research Corp.
M. E. Merchant, Cincinnati Milling Machine Co.
E. A. Saibel
B. Sternlicht, General Electric Co.
A. Cameron, Imperial College of Science and Technology, London, England

Abstracted by Engineering Index and Industrial Arts Index

LUBRICATION ENGINEERING is published monthly by the American Society of Lubrication Engineers, 84 E. Randolph St., Chicago 1, Illinois. Current volume single copies 75c. Copies of issues from previous volumes $1.00, if available; copies to foreign addresses add 50c per copy. Annual subscription $6.00 in the USA and Canada, $7.00 to all other countries. Copyright by the American Society of Lubrication Engineers. ASLE will not be responsible for statements or opinions presented at its meetings or printed in its publications. Second class postage paid at Chicago, Ill., and Richmond, Va.

Foreign Technical Information Center

A Foreign Technical Information Center is now operating in the U. S. Department of Commerce to provide American science and industry with access to translations of a large amount of Soviet technical information.

The Center is a part of the Office of Technical Services, Business and Defense Services Administration, with John C. Green as Director of OTS.

"This program will add substantially to the wealth of technical information that OTS can supply to industry in any field," Secretary of Commerce Sinclair Weeks said.

"The OTS is already well equipped to conduct such a program. Since 1945 OTS has been collecting, cataloguing and publishing reports resulting from U. S. Government-sponsored research.

"Also, immediately following World War II the Office acquired, cataloged and published the large volume of technical papers captured by the Allies in Germany. Its services were materially strengthened in 1955 when arrangements were made with the Atomic Energy Commission for the prompt release through OTS of a much larger volume of AEC material than OTS had handled in the past. In recent years sales of reports have registered substantial annual increases."

The services of the Foreign Technical Information Center include publication of abstracts of all articles appearing in 141 Soviet technical journals, translations of important sections of *Referativnyy Zhurnal* (the Russians' own abstract journal), and a semi-monthly review of various areas of Soviet science compiled by the Central Intelligence Agency. Abstracts of each issue of the 141 journals may be purchased from OTS on a subscription or single issue basis, as may CIA's *Scientific Information Report*. The various sections of *Referativnyy Zhurnal* will be sold initially by single issues, but subscription sales may be offered later.

OTS will soon begin distributing complete translations of articles and books, Director Green said. Translations will be listed in an abstract journal to begin publication about September.

Much of the material collected by OTS will be from Government sources, principally the intelligence agencies. This volume is estimated to run at 50,000 abstracts and 10,000 complete translations a year. Eventually, material from other sources is expected to be added to the collection. This will provide a central point to which science and industry may look for comprehensive information on Soviet bloc developments, Mr. Green stated.

Congress appropriated $510,000 for the operation of the foreign technical information program in fiscal 1959. Functions of the program are to collect, catalog, print, and sell abstracts and complete translations of foreign technical documents.

Supplier Tells Fluid Differences

The present complexity of the field of fire-resistant hydraulic fluids—4 types, a dozen suppliers, 30-odd brand names, varying prices and degrees of fire resistance—places growing responsibility upon suppliers of these products to assist users in making the proper selections.

Acting on this premise, E. F. Houghton & Co., Philadelphia supplier of all four basic fluid types, attempts to spell out, through applications research, the salient differences among fluids.

The actual reason for the wide range of fluids now available, says Houghton, is simply that no one fluid has the universal characteristics of petroleum oil. In fact, every fire-resistant fluid has characteristics markedly different from oil which can lead to unsatisfactory hydraulic performance. But by correlation of fluid properties with design characteristics of a system, the Philadelphia firm claims it can pinpoint the fluid type which will perform best with little or no system re-design.

Phosphate esters are the most widely applicable. But they can not be used with equal success in all types of equipment. In certain pumps, for instance, neither esters nor water-glycol fluids are fully satisfactory. Restricted pump intake conditions are aggravated by the high density of the fluid. These pumps should be modified to handle the fluids.

A fire-resistant fluid should be chosen only after a study of equipment details. Fluid performance can be predicted if sufficient equipment data is at hand.

A flat statement that phosphate ester fluid provides better bearing life than water-glycol is not justified, according to the following results of tests run by Houghton hydraulics engineers:

1. Balanced vane pumps have negligible bearing loads so have no bearing trouble when operating with water-glycol fluids.
2. Most axial piston pumps have sufficient bearing capacity to use water-base fluids satisfactorily.
3. Some gear-type pumps have inadequate bearing capacity for good use of water-base media. But those with plain bearings do well.
4. Water-base media perform poorly in radial piston pumps, due to inherent rust problems within the pump case, and to the shorter bearing life which results.
5. Screw-type pumps perform well with water-base fluids.

In general, pumps with plain bearings perform best with water-base fluids. Unbalanced vane and gear pumps can be modified with plain bearings to improve operation with water-base fluids. Other pumps can be modified with higher capacity anti-friction bearings.

According to Houghton, there is ample data now available from several sources to help users achieve a high degree of fluid-packing compatibility. Essentially, water-glycols have no effect on standard rubber or leather packings unless the pH rises to a high level. They do affect cork composition shaft seals, but these can usually be replaced with rubber.

When using a phosphate ester fluid, special attention should be given to packings and seal materials:

1. Dynamic seals should be butyl rubber, silicone, or Teflon.
2. Static seals are not critical.
3. Packing changes, especially dynamic seals, should be made at the time of installation of the fluid.

The most apparent indication of fluid-packing incompatibility is packing swell. Swell varies widely among various fluids and packings, as indicated by the results of the ASTM Rubber Swell Test.

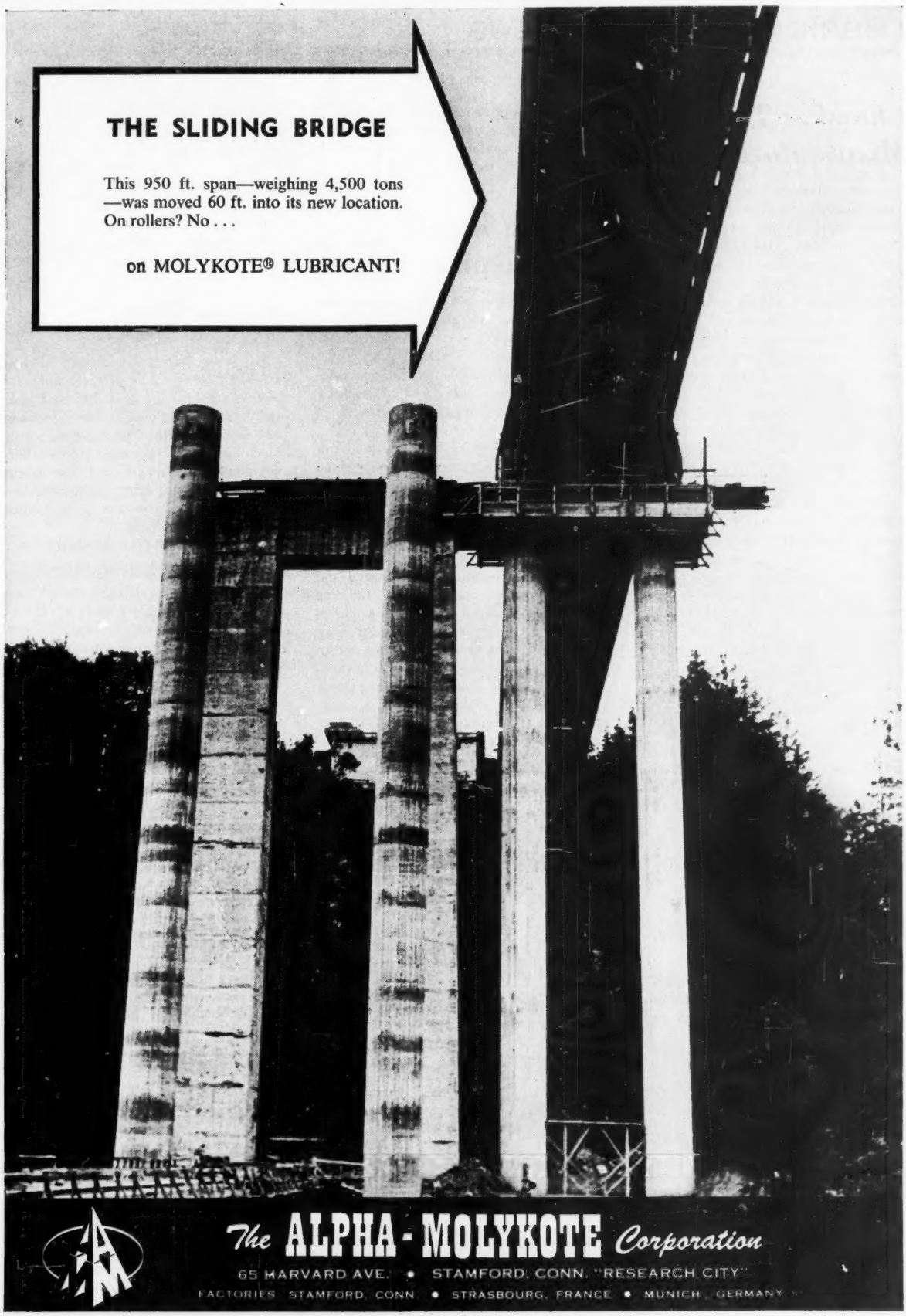
Taking 15% as a recommended maximum swell figure, it is apparent that Buna N packings and phosphate ester fluids are incompatible. This is also true of the esters with the fabricated duck and Neoprene.

Analysis of the above esters for content of chlorinated materials has shed light on the wide differences in swell between esters *A* and *D*, and *B* and *C*. Fluids *B* and *C* contain appreciable amounts of chlorinated materials which accounts for their deterioration.

Phosphate ester fluids do not contribute to the formation of rust or corrosion. However, unless fortified with conventional petroleum type rust inhibitors, they do not offer protection against rust in wet or humid conditions.

Water-glycol media have a corrosive effect on zinc and cadium. But at proper

(*Cont. on p. 40*)


THE SLIDING BRIDGE
This 950 ft. span—weighing 4,500 tons —was moved 60 ft. into its new location. On rollers? No . . .
on MOLYKOTE® LUBRICANT!
The ALPHA-MOLYKOTE Corporation
65 HARVARD AVE. • STAMFORD, CONN. "RESEARCH CITY"
FACTORIES STAMFORD, CONN. • STRASBOURG, FRANCE • MUNICH, GERMANY

Chamber Tests Missile Parts

A new environmental temperature altitude chamber capable of simulating altitudes up to 200,000 feet has been acquired by New York Testing Laboratories, Inc. of New York City. The chamber is especially designed to test components that will go into the manufacture of space vehicles and missiles.

The chamber will be used in connection with an overall reliability program instituted by government agencies to make sure components used in space aircraft, missiles and rockets perform satisfactorily under all possible conditions. N. Y. Testing has been certifying components manufactured by private suppliers on government contracts.

The purpose of the reliability programs is to bring performance of components up to 100% efficiency under any possible conditions. Presently efficiencys of 99.99% are not enough. Most missiles and space craft have thousands of components in the form of transformers, resistors, switches, gears, etc. When the efficiency of the entire unit is totaled up it sometimes adds up to only 75%.

For instance, N. Y. Testing is being used by a manufacturer of a fire control system for a supersonic bomber and for ground support equipment. The lab will screen all sub-contractors and suppliers of strategic materials to insure reliability of the entire unit.

"Moon Building" In Blueprint Stage

Plans for a permanent "moon building" to house living quarters for moon explorers, laboratories for scientific research, maintenance shops for space vehicles and stations for earth-moon communications have been announced by the Wonder Building Corporation of America, Chicago.

A detailed 5 by 6 foot scale model of the structure—a cigar shaped corrugated metal cylinder covered by a protective metal "meteoric shield"—was recently unveiled to military and federal government officials at a presentation in Washington, D. C.

The moon building was designed and engineered by the Wonder Building Corporation under the technical direction of Dr. John S. Rinehart, Professor of Mining Engineering and Director of the Mining Research Laboratory, Colorado School of Mines, and former Associate Director of the Smithsonian Astrophysical Observatory, Cambridge, Mass.

Dr. Rinehart said that because of the present lack of knowledge and great divergence of opinion concerning the moon's surface, the moon building has been designed for the worst condition anticipated—a sea of dust upon which the building would float, anchored by heavy weights suspended by cables from the body of the structure. If the moon's surface proves to be sufficiently solid, it could then provide normal support for the building.

In actual size, the moon building would be 340 feet long, 160 feet wide and 65 feet high. Including air lock and plastic observation bubble, it would measure 520 feet in length. The building would be fabricated of aluminum alloys which combine high strength and low weight with ease of fabrication. Aluminum also provides a good reflecting surface which aids cooling problems.

Above and separated from the roof of the building is a slightly curved umbrella-shaped protective meteoric shield, designed to ward off the gnatlike rain of interplanetary meteoric dust which descends with great velocity on the barren surface of the moon. The shield would be 460 feet long, 380 feet wide and 83 feet high.

ASLE Dept. PP 1.
84 E. Randolph
Chicago 1, Ill.

Gentlemen:

Please send me the following preprints from the Joint Lubrication Conference. Enclosed please find _____ (each preprint $.50 for members, $.75 for nonmembers).

Name_____

Company_____

Address_____

City_____ State_____

Section_____

(State number of copies desired in box)

☐ 58LC-1. "Development of Radiation Resistance Oils," by J. G. Carroll and R. O. Bolt

☐ 58LC2. "The Effects of High Energy Ionizing Radiation on Turbine Oil Performance Characteristics," by C. F. Kottcamp, R. P. Nejack, and R. T. Kern

☐ 58LC-3. "Visco-Elastic Behavior of Greases," by E. O. Forster and J. J. Kolfenbach

☐ 58LC-4. "An Analytical Study of the Effect of Offset Loads on the Performance of an 120° Partial Journal Bearing," by A. A. Raimondi

☐ 58LC-5. "Development of Seals for Rocket-Engine Turbopumps," by J. E. Wolf and R. E. Connelly

☐ 58LC-6. "A Study of Design Criteria for Oscillating Plain Bearings," by W. A. Glaeser and C. M. Allen

☐ 58LC-7. "Adhesion Between Metals and Its Effect on Fixed and Sliding Electrical Contacts," by W. P. Mason

☐ 58LC-8. "Transition Temperatures in Sliding Systems," by R. S. Fein, C. N. Rowe, and K. L. Kreuz

☐ 58LC-9. "Wear and Friction of Filled Polytetrafluoroethylene Compositions in Liquid Nitrogen," by D. W. Wisander, C. E. Maley, and R. L. Johnson

☐ 58LC-10. "The Conduction of Current in Bearings," by H. N. Kaufman and J. Boyd

☐ 58LC-11. "A Surface Effect Associated with the Use of Zinc Dialkyl-Dithiophosphate-Treated Oils," by P. A. Bennett

☐ 58LC-12. "Film Formation by an Anti-Wear Additive in an Automotive Engine," by M. J. Furey

☐ 58LC-13. "Testing and Operation of Ball Bearings Submerged in Liquefied Gases," by K. B. Martin and R. B. Jacobs

☐ 58LC-14. "Effect of Fibre Orientation, Temperature and Dry Powder Lubricants on Rolling Contact Fatigue," by W. J. Anderson and T. L. Carter

☐ 58LC-15. "Rolling Contact Fatigue Evaluation of Bearing Materials and Lubricants," by E. G. Jackson

☐ 58LC-16. "Materials in Rolling Element Bearings for Normal and Elevated (450°F) Temperatures," by T. W. Morrison, H. O. Walp, and R. P. Remorenko

let your imagination run wild

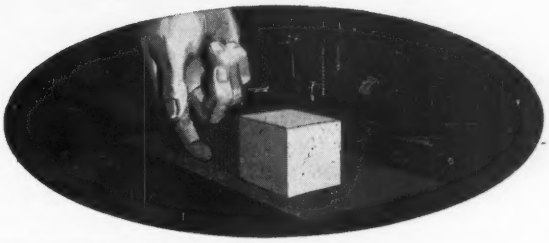
with this coating

EMRALON . . . Acheson's revolutionary new dispersion "opens the door" to a host of "restricted" applications

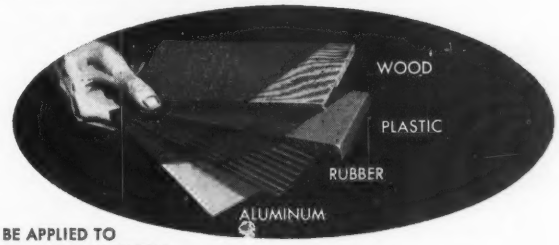
Five years in development, 'EMRALON' surface coatings now make possible the application of Du Pont Tetrafluoroethylene (TFE) to heat sensitive materials such as aluminum, rubber, wood and plastic. Applied by spray, these versatile resin-bonded lubricating films exhibit the low-friction properties of the TFE pigment together with the durability of their specially-selected binders. Thus, hundreds of potential uses which heretofore were impractical because of the high fusing temperature of other processes, can now be reconsidered as workable applications.

First in the Acheson family of TFE dispersions is 'EMRALON' 310,* employing a phenolic binder. Requiring a one-hour cure at only 300°F., it provides an unparalleled combination of low-friction coefficient, toughness, flexibility, adhesion and corrosion resistance. Substrates even more sensitive to temperature, or those where a bake cure is not practical, can be coated with 'EMRALON' 320† air-drying counterpart to 'EMRALON' 310.

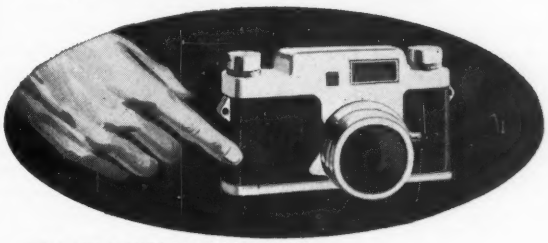
Evaluate 'EMRALON' 310 or 320 in your plant and be among the first to "open the door" to new design possibilities. Send for an introductory package complete with data sheet. Enough to coat 5,000 sq. in. of surface is yours for $4.25 prepaid ($4.50 west of the Rockies). Write today.



LOW COEFFICIENT OF FRICTION



MAY BE APPLIED TO HEAT-SENSITIVE MATERIAL



IDEAL FOR LIGHT LOAD MECHANISMS

Acheson Colloids Company
Port Huron, Michigan

Gentlemen: Your new 'EMRALON' surface coatings suggest themselves as possibilities for a current design problem. Send an introductory package to me promptly.

- ☐ 'EMRALON' 310 (bake type)
- ☐ 'EMRALON' 320 (air-dry)
- ☐ Bill me on Order No._____
- ☐ Check enclosed
- ☐ Please have your service engineer call:

NAME: TITLE:

COMPANY:

ADDRESS:

CITY: STATE:

APPLICATION:

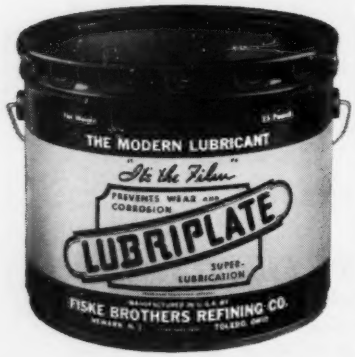
*'EMRALON' 310 is manufactured under exclusive license from E.I. du Pont de Nemours & Co. (Inc.) under U. S. Patent 2,825,706. Not licensed for use or for sale for use in providing electrical insulation.
†'EMRALON' 320 — Patent applied for

ACHESON *Colloids Company*
PORT HURON, MICHIGAN
A division of Acheson Industries, Inc.
Also Acheson Industries (Europe) Ltd. and affiliates, London, England

Lubriplate No. 630-2 is a high temperature, extreme pressure, water-repellent, grease type lubricant. Ideal for the general lubrication of Industrial, Automotive, Construction, Farm and Marine Equipment. Lubriplate Grease Gun Cartridges provide an easy, quick, economical means of application. Prevent the waste and mess of hand filling. Packed 10 Cartridges in a handy carrying carton.

REGARDLESS OF THE SIZE AND TYPE OF YOUR MACHINERY, LUBRIPLATE LUBRICANTS WILL IMPROVE ITS OPERATION AND REDUCE MAINTENANCE

For nearest LUBRIPLATE distributor see Classified Telephone Directory. Write for free "LUBRIPLATE DATA BOOK"... a valuable treatise on lubrication. LUBRIPLATE DIVISION, Fiske Brothers Refining Company, Newark 5, N. J. or Toledo 5, Ohio.



NEW PRODUCTS

JOURNAL LUBRICATOR

A new journal lubricator for railroad cars has been developed by Premier Manufacturing Corporation. Unlike any lubricator previously available, the Premier is based on a combination of wool felt, foam neoprene and chenille. This combination is said to permit superior journal lubrication at low cost. The Premier is composed of these elements: wool felt base, twin foam-neoprene center cores, and cotton duck covering with disturbable chenille wicking loops. The manufacturer reports that the Premier provides low journal operating temperature with low sensitivity to dirt. The wool felt base serves as an oil reservoir, prevents damage to the lubricating pad and eliminates danger of "wick grabs" by the bearing. A twin foam-neoprene design was selected so that positive journal contact could be achieved without excess pressures which cause elevated operating temperatures. Also, best wicking action is obtained in the center section between the neoprene cores. A unique feature of the Premier allows two strands of tufts (72 wicks) to be clear of the journal on each side. As the car starts to move, the oil-saturated tufts from one side are drawn under the journal, immediately depositing a quantity of oil. This feature is of particular significance during cold weather operations. Additional details on the Premier Journal Lubricator may be obtained from Premier Manufacturing Corp., 107 Penn Avenue, Pittsburgh 21, Pa.

WEATHERLAB CABINETS

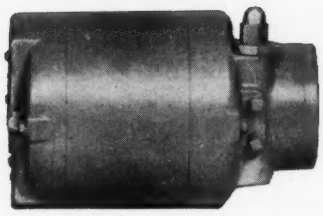
A new line of combination high and low temperature-humidity environmental cabinets is now being manufactured by the Hudson Bay Co., division of Labline, Inc. Produced under the trade name "Weatherlab," the cabinets can sustain temperatures from —120F to 350F and humidities from 20% to 98%. Models range in size from 5 cubic ft. to large walk-in types. All units have heavy, double wall construction. Interiors are made of Monel metal for maximum resistance to corrosion, exteriors are formed of stainless steel. Fibreglas insulation is used throughout with a minimum protective thickness of six inches. In addition, all insulation is vapor sealed to prevent deterioration. Thermopane windows in doors and penetrations in the walls can be supplied whenever required. The cabinets are reported to be equipped with high pressure, large volume air blowers to assure uniform temperature throughout the chamber. Humidity is supplied and controlled through a water float, feed valve and electrically heated steaming chamber or a separate, electrically heated steam generator, mounted externally. The "Weatherlabs" have a wide variety of applications. Some of these are: testing guided missile parts, electrical components, radio and television parts, paints and other protective coatings, rubber and plastic parts, packaging components, road materials, effect of corrosion, and mil. specifications.

SOLID FILM LUBRICANT

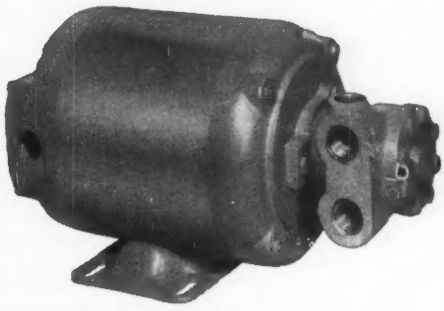
Electrofilm, Inc. of North Hollywood, California, has reportedly developed an effective solid film lubricant which greatly increases the wear life of moving parts operating in oil or grease. This improved solid film lubricant has several features that are said to distinguish it from other solid film lubricants. (1) It contains small particles of lead, tin and graphite which are well-known for their ability as bearing materials. (2) The semi-porous nature of #4856 absorbs oil and acts as a reservoir against metal to metal contact under high loads, and especially during long shutdown periods —it is also compatible with additives in modern oils and greases. This solid film lubricant was first developed for use on titanium under loads so heavy that oil or grease alone was inadequate as a lubricant. However, with #4856 preventing metal to metal contact, galling and seizing is prevented. Typical applications include spherical bearings, clutch assemblies, leather oil seals, spline assemblies, bearing cages, sleeve bearings, piston cylinders, valve stems and hydraulic actuator parts. Technical Bulletin #2056 is available from Electrofilm Technical Service, North Hollywood, California.

SOLENOID VALVES

Announcement of brand new 2-way and 3-way solenoid valves marks the entry of the C. A. Norgren Co., Englewood, Colo., into the valve manufacturing field. The first models incorporate several unusual design and construction features that provide a quality valve with greater flow, higher operating pressure, longer life and ease of maintenance. Series A, now available in ⅛ inch and ¼ inch pipe sizes, includes 2-way, 3-way and directional solenoid valves in both normally closed and normally open types. All Series A types are offered with a stainless steel body or a brass body with stainless steel seat insert; either grommet or conduit type electrical outlets are available. Series B is a midget, 2-way normally closed valve with ⅛ inch NPT ports.

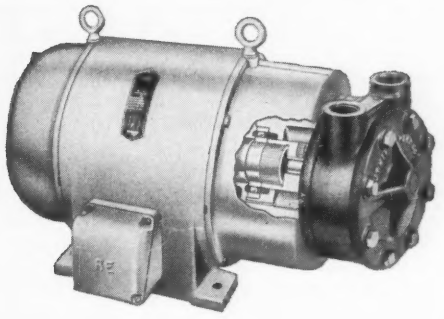


1



2

3 NEW TUTHILL close coupled pump and motor units



3

Save space, Save weight, Cut costs

Now TUTHILL offers three pump and motor combinations developed specifically for applications where space or weight are at a premium. Furnished in a wide variety of sizes and styles, one of these combinations can provide savings in hydraulic, oil burning, lubrication or other services.

The small size of these combinations solves design problems. By reducing weight they cut shipping charges. The elimination of couplings, adapters and bases means lower costs. And even more important savings are often made through the simplification of installation procedures.

Available from Stock

A wide variety of combinations are available immediately from stock, in either large or small quantities.

For example, Number 1 above is TUTHILL's famous POWERMITE—a combination in which pump and motor are incorporated in one unit which takes up no more space than a standard electric motor (the POWERMITE shown measures only 3⅞" x 7½").

Originally restricted to large quantity applications some POWERMITE models are now available from stock for small quantity orders. The unit shown is rated for 16 GPH at 350 PSI.

For other small quantity applications TUTHILL provides a complete selection of close coupled units with the pump mounted directly on the motor. Numbers 2 and 3 above are typical.

For applications, such as hydraulics which require smaller pumps, units such as Number 2 above provide outstanding advantages. Normally they can reduce space required for pump and motor by at least 6 inches, and cut weight by several pounds. Capacities range from 20 to 300 GPH. Pumps are available for pressures up to 1500 PSI.

Larger pump and motor combinations, such as Number 3 above, can be provided with capacities up to 50 GPM, for pressures up to 400 PSI.

If you are trying to put a pump and motor into a small space, TUTHILL has the answer. Write for details.

Tuthill Manufactures a Complete Line of Positive Displacement Rotary Pumps in Capacities From 1 to 200 GPM; for Pressures to 1500 PSI; Speeds to 3600 RPM.

TUTHILL PUMP COMPANY

971 East 95th Street, Chicago 19, Illinois

PUMPS FOR YOUR PURPOSE

TUTHILL PUMP COMPANY
971 East 95th Street, Chicago 19, Illinois

☐ Please forward complete information on TUTHILL close-coupled Pump and Motor Units for_____GPH at_____PSI.

☐ Please have your representative call.

NAME_____ TITLE_____

COMPANY_____

STREET_____

CITY_____

STATE_____

NEW PRODUCTS

MOBILE DISPLAY UNIT

The Aro Equipment Corporation, Bryan, Ohio, will spearhead its 1959 lube equipment sales program with a new Mobile Display Unit. It is named, appropriately, the M-D, and it is the first unit of its kind in the lube equipment market. The M-D is a custom-built van fitted with basic Aro equipment recommended for a modern lubrication department. A built-in generator and compressor allows this equipment to be operated instantly, without need of an outside power source. Aro believes that the M-D finally overcomes many of the problems involved in field sales meetings and demonstrations. Conventional field demonstrations usually require elaborate preparation. A room must be located and then supplied with mounting facilities and a compressor. The lube equipment itself must then be trucked to the location, carried into the building and carefully installed. Visitors who are asked to attend such a meeting must often sacrifice considerable time to do so. By contrast, the M-D is ready for demonstration anywhere, whether in a parking lot or alongside the curb. The interior of the van is 12 feet long and 6 feet 4 inches high, and will accommodate 6 men comfortably. Weather is no problem, since the M-D carries its own climate in an air conditioner and heater. An electric refrigerator and coffee maker allow refreshments to be served. A visitor entering the M-D will see Aro lube equipment installed exactly as it would be in a service station. All tubing, fittings, regulators and other hardware are linked in their correct sequence and will show a visitor how an installation should be laid out. Equipment consists chiefly of pumps, standard-length hose reels and cabinet models. Aro will display the M-D at the I.A.S.I. Show in February. Immediately after the show the van will be scheduled out to the Division Managers. The Division Manager in any territory will have the M-D for a period of from one to four weeks. He will utilize the van for helping to close out pending sales, if necessary. The M-D will allow several sales meetings per day, and the only preparation needed will be an appointment with desired visitors. The company's field men have already voiced strong enthusiasm for the M-D. Consideration is now being given to the construction of one or two additional M-D units. Whatever the ultimate benefits may be, Aro's sales staff now claims that it can conduct a live sales demonstration on a frozen ice-cap or a blazing desert, with short notice and little effort.

PILLOW BLOCK BEARINGS AVAILABLE

Hoover Ball and Bearing Company has announced new pillow block ball bearings that are "sound-conditioned" and expressly designed for applications where extremely quiet operation is essential. These newly introduced bearings incorporate a synthetic rubber cushion between the bearing's outer ring and the pillow block housing to insulate against vibration and suppress noise. Like all Hoover ball bearings, these pillow block units are made with high-quality "Hoover Honed" raceways and "Micro-Velvet" balls, additional assurances of quiet bearing operation. Housings for "sound conditioned" Hoover pillow blocks are of a lightweight, ductile material that resists shock and vibration. The units are available in five shaft sizes from ½ inch through 1 inch. Offered as a separate unit is the component simplex machine unit bearing of these pillow blocks. It consists of a prelubricated, single row bearing with large balls and deep raceways, plus two seals and a wire lock ring for use in mounting. Outer diameter of the bearing is enclosed with the oil-proof synthetic rubber cushion used in Hoover "sound-conditioned" pillow blocks. For information about the new Hoover pillow blocks and flangers, send for the recently issued 12-page Hoover Bulletin No. 106. Write Advertising Department, Hoover Ball and Bearing Company, 5400 South State Road, Ann Arbor, Michigan.

NEW POLYMER USED IN GARLOCK PACKINGS

Viton, the versatile new broad temperature range polymer developed by DuPont which has proved so successful in military aircraft and missile applications, is now being used to manufacture vital packings, seals and gaskets by The Garlock Packing Company of Palmyra, New York. Garlock has developed basic formulations of Vitron with durometer hardness ranging from 60 to 90. These formulations will be used in manufacturing "G" rings, Chevron packings, Klozure oil seal elements, Mechanipak mechanical seal bellows, sheets, molded and extruded shapes for application in which maximum resistance to deterioration by heat, oils, solvents and many corrosive liquids is essential. Viton is unequalled for service against oils and solvents at temperatures over 400F., and it is highly resistant to ozone and weather deterioration.

ASLE MEMBERSHIP CLASSIFICATIONS

Membership in the American Society of Lubrication Engineers is in several grades as defined below. Assignment to grade is made by the Admissions Committee or Board of Directors on the basis of information submitted by the applicant.

Members: Members shall be persons not less than 24 years of age who: (1) are engaged in research and instruction at technical schools, universities, and various publicly and privately supported institutions in the field of lubrication; or (2) have occupied recognized positions as lubrication engineers for a period of three or more (not necessarily consecutive) years prior to date of admission, involving the responsibility for or supervision of the development, selection, field use and application of lubricants as differentiated from other activities; or (3) are indirectly concerned with the field of lubrication, but possessing other qualifications of experience, knowledge, and accomplishment, and have manifested a particular interest in the purposes and welfare of the Society to the extent that their membership would be a valuable contribution to the successful functioning of its activities. Fee 15.00.

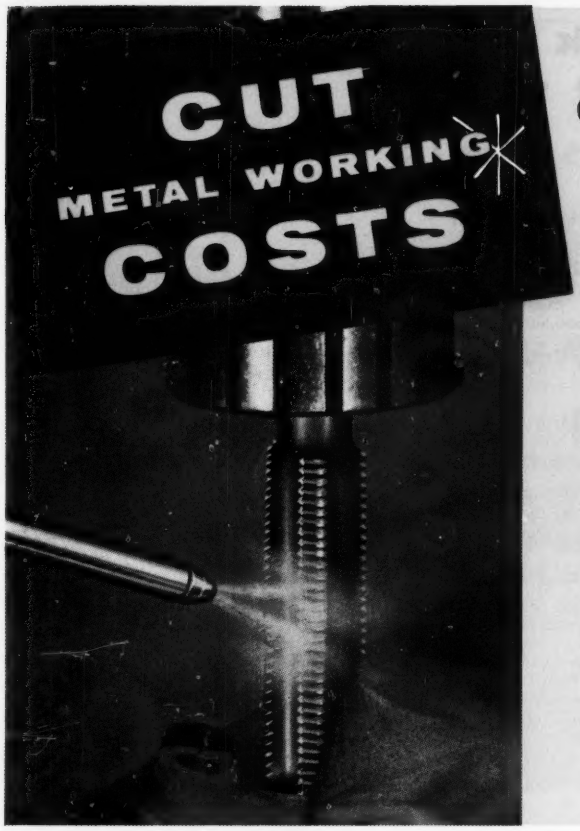
Associate Members: Associate Members shall be persons less than 24 years of age, and those who do not completely fulfill the membership requirements for Members. Fee $7.50.

Sectional Sustaining Members: are such persons or organizations as may be interested in and desire to contribute to the support of the purposes and activities of a local Section of the Society. Fee $25.00.

Industrial Members: Industrial Members are such persons or organizations as may be interested in and desire to contribute to supporting the purposes and activities of the Society. Fee $150.00.

For application blanks or further information, write:

ASLE
84 E. Randolph St.
Chicago 1, Ill.

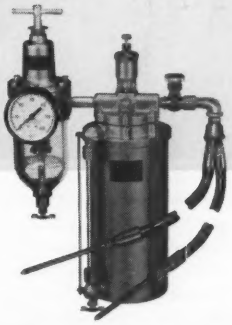


...with

Norgren SPRAY-LUBE UNITS

for single or dual point applications on tapping, drilling, milling, and grinding operations.

- ✳ LESS MACHINE DOWN-TIME
- ✳ INCREASED TOOL LIFE
- ✳ BETTER FINISHES



Lubrication Exactly Where Needed

Norgren Spray-Lube applies a fine spray of coolant directly to the tool or cutting area—at the location that provides the most efficient lubrication and cooling action.

Faster Cooling Speeds Production

A few ounces of sprayed coolant extracts more heat from the tool than gallons of the same fluid flooded over the workpiece and tool. Cutting, tapping, and grinding can be faster—output is increased—tool maintenance costs are reduced.

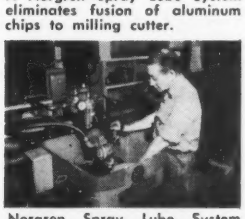
Reduced Coolant Consumption

With fine spray, less coolant does a better job of cooling and lubricating—cuts costs.

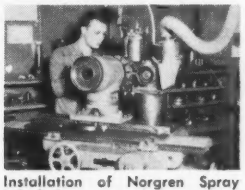
Better Working Conditions

No messy pools of liquid on machine or floor. Unobstructed view of work. No splashing of liquid. Machine easier to clean. Machined parts cleaner to handle.

A Norgren Spray Lube System eliminates fusion of aluminum chips to milling cutter.



Norgren Spray Lube System delivers a fine, cooling spray that reduces wheel wear. Permits full view of workpiece.



Installation of Norgren Spray Lube System ended cracking of carbide-tipped cutters during sharpening—diamond wheels last twice as long.

If it's Norgren...It's Dependable.

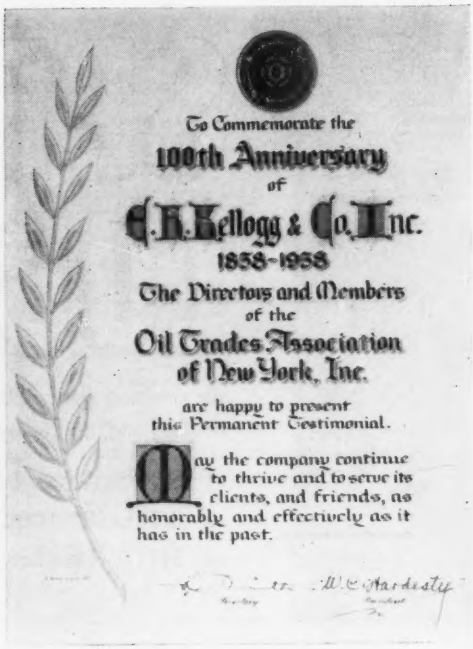
For complete information about Norgren SPRAY-LUBE, call the nearby Norgren Representative listed in your telephone directory—or WRITE FACTORY FOR COMPLETE INFORMATION.

C. A. NORGREN CO.

3434 SOUTH ELATI STREET ENGLEWOOD, COLORADO

News Notebook

ASLE was well received at the National Lubricating Grease Institute's 25th annual meeting. Among those present were (left to right) John Shaw, Assistant regional manager, du-Pont deNemours; Earl Youse, membership chairman, New York section, C. L. Willey, ASLE executive secretary; Edwin M. Strom, Jr., program chairman, New York section, and George Kellis, chairman, New York section.



At its annual dinner at the Waldorf-Astoria Hotel, the Oil Trades Association of New York presented the E. H. Kellogg Co. with this plaque in honor of the company's 100th anniversary. The plaque was accepted by C. F. Moore, company president, who joined the firm as lubrication engineer after service in World War II. Mr. Moore is a long-time member of the American Society of Lubrication Engineers.

Mrs. F. A. Popejoy of Allen Lubricants Co. discussed dry film coatings at a recent New York section meeting.

National President J. D. Lykins and Hudson-Mohawk Chairman J. P. Thomas got together at December section meeting, largest ever held by Hudson-Mohawk.

Recent Finance Committee meeting was attended by (left to right) R. J. Sealy, R. Kraus, W. Hoch, Committee Chairman C. C. Blaisdell, J. Waddell, Director-Sponsor D. M. Cleaveland, and Treasurer J. W. Peterson.

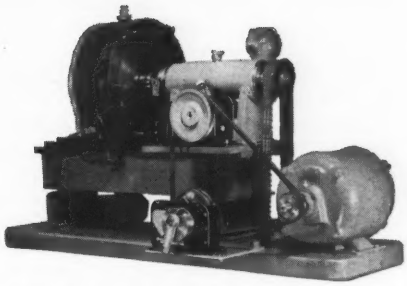
Automatic transmission seal problem—

New National Syntech® proves dependable answer in front pump seal position

Constant temperatures of 250°F, peaks of 300°, continual change in shaft speed, and total inaccessibility of the seal without costly teardown—these are a few of the sealing problems in the front pump of today's automatic transmissions for passenger cars.

To help meet this challenge, National engineers have produced a new oil seal. The new design, a steel encased, spring-loaded unit with Syntech synthetic sealing lip, is characterized by an unusually long flex section in the lip, a special, light-loading tension spring, and the time-tested, low torque Syntech lip itself.

Factory engineers report that the new National seals are proving extremely reliable in the application. Dealers also find the front pump seals are very reliable and do not require early replacement.



To design and thoroughly test the new seal, National engineers developed a new transmission simulator which exactly duplicates front pump operating conditions at all car speeds.

Get real help on seal engineering problems. Call the National Engineer.

NATIONAL SEAL Division, Federal-Mogul-Bower Bearings, Inc.

General Offices: Redwood City, California; Plants: Van Wert, Ohio, Downey and Redwood City, California

AT A FAMOUS ORDNANCE PLANT IN NORTHERN LOUISIANA:

600-Ton Lubrication Job for Cities Service!

The huge 600-ton press above is one of several at a well known Louisiana ordnance plant operated by the Remington Rand Division of Sperry Rand Corporation.

A big machine, it naturally poses a big lubrication job... but not so big that Cities Service Pacemaker Oil can't take it in stride. With unusually high viscosity index and superior fortification against oxidation, corrosion and rust, Pacemaker is a natural for the task.

Likewise, throughout the various stages of producing artillery shells—the end product—Cities Service lubricants are hard at work.

Clearly, there's little room for error here—either in the product itself or in the machines that make it. That's why Cities Service lubricants were chosen . . . and it's an equally good reason for making them *your* choice.

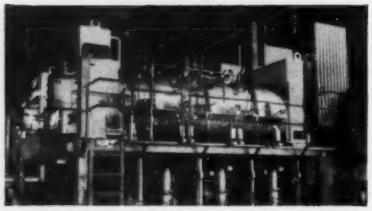
For a survey of your plant's lubrication needs, talk with a Cities Service Lubrication Engineer. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

HOW THE ORDNANCE PLANT USES CITIES SERVICE LUBRICANTS

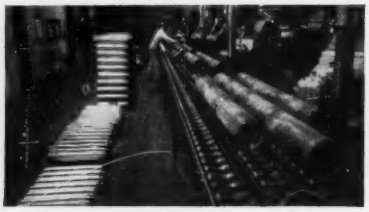
MACHINE	LUBRICANT
Large presses	Pacemaker 3 Hydraulic Oil
Airlines	Pacemaker 1
Speed reduction units	Pacemaker 6
Worm gear reduction units	Optimus 6
Package compressor units	Pacemaker 5
Metal working machines requiring a water soluble cutting oil	Chillo A
General Lubrication	Trojan Gear Oils, Trojan H-2 Grease

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS



High Speed Gas Furnace heats steel to 2660 degrees F. All lubrication is supplied by Cities Service products.



Partially Finished Shells await final forming. Unusual number of forming operations are required to produce final product.

Forming Press does final forming of artillery shells. The press is lubricated by Cities Service Pacemaker Hydraulic Oil.

in'dis·pen'sa·ble
is the word to describe

"A Survey of Journal Bearing Literature"

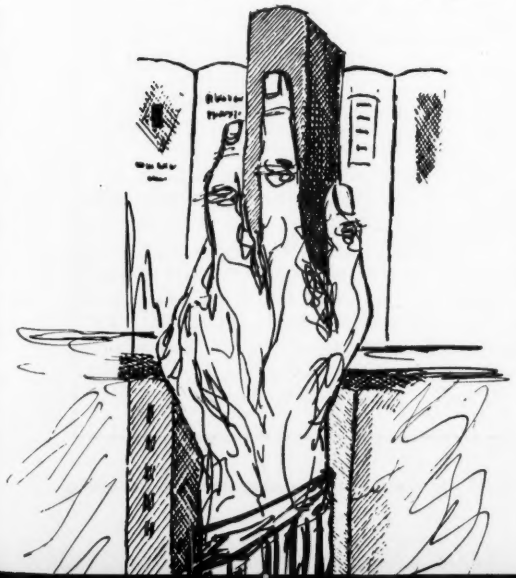
by Professor Dudley D. Fuller, Columbia University.
A research project financed by the American Society of Lubrication Engineers with the cooperation of industrial sponsors.

"A Survey of Journal Bearing Literature" **belongs** on the shelf of your reference library. Now, for the first time, you need consult only one source for a complete evaluation of over 2500 references related to the field of journal bearings. No need to search through volume after volume of reference material in order to find specific information. Find the information **you** need in minutes instead of hours.

Here is a comprehensive picture of all literature dealing with journal bearing analysis, design, performance and maintenance — 563 of the most authoritative works in abstract form plus a 100 page report and evaluation of references most useful to those whose livelihood depends on their knowledge of the design and operation of journal bearings.

This is the book that enables you to quickly locate the best source of information on bearings — the book that highlights and reviews **all** information on the subject in its most usable form.

This 260 page volume, durably bound in rich brown, simulated leather is one you will use for many years as an "always ready" reference. All the information you'll ever need to solve your journal bearing problems in one complete book—only $15.00. Order your copy today—just fill out the order form and return it to us with your check or money order—we'll ship you the book postage paid.



American Society of Lubrication Engineers
Department SU-1
84 East Randolph Street
Chicago 1, Illinois

Please send me _____ copies of "A Survey of Journal Bearing Literature" @ $15.00 each.

☐ Remittance enclosed ☐ Bill me ☐ Bill company

Name_____

Company_____

Address_____

City_____ State_____

BOOK REVIEW

"Vapor-Liquid Equilibrium" Eduard Hala, Jiri Pick, Vojtech Fried, and Otaker Vilim. Pergamon Press Ltd. 1958

The authors of this interesting book have set themselves the task of providing in one volume a theoretical and experimental treatment of the important subject of vapor-liquid equilibrium for the use of industrial workers in the field of distillation. It is addressed specifically to this group of chemists and chemical engineers. This present volume, which is the second edition, was especially prepared for translation into English, which has been ably done by G. Standart. The book consists of three main parts. The first presents the thermodynamics of solutions of non-electrolytes as applied to vapor-liquid equilibrium. The second part is a compendium of basic experimental techniques for getting vapor equilibrium data. The third part gives the results of an exhaustive search of vapor-liquid equilibrium data published up to February 1957.

Part I begins with three short introductory chapters covering basic thermodynamic relations, and the concepts of ideal and real solutions. Then follows the principal part, a somewhat lengthy chapter entitled "Vapor-Liquid Equilibrium in real systems." This chapter comprises five main divisions dealing with, first, systems in which the constituents are miscible in the liquid phase and the vapor phase is ideal; second, systems in which the constitutents are partially miscible in the liquid phase and the vapor is ideal; third, activity coefficients and physical properties of pure constituents; fourth, the real vapor phase; and, fifth, calculation of equilibria from indirect data. This chapter, like much of the book, is rather compactly written and is not easy reading. The authors render a valuable service to the reader by giving 18 examples of calculations illustrating the mathematical methods developed. Thus, example No. 7 is the determination of the constants in the Redlich-Kister equation of the third order from direct determinations of equilibrium composition, example No. 16 is the calculation of the equilibrium ratio of benzene in a mixture of aromatic hydrocarbons at 200°C and a total pressure of 10 atmospheres. These sample calculations will enhance the value of the book to the practicing engineer wishing to use it as an aid to the solution of his design problems.

Part II deals with the laboratory technique for getting the data to be treated by the methods of Part I. The subjects dealt with are, criteria of purity, measurement of temperature and pressure, vapor pressure and boiling point, and the direct experimental determination of vapor-liquid equilibrium. This part of the book is extremely practical and will be useful to the experimentalist. For example, the reader is warned that even the best glass thermometers show a drift of 0.01° to 0.04° per year, owing to shrinkage of the glass. Again the authors illustrate by 10 examples the methods given for treating experimental results. Thus example No. 3 deals with the inertia of thermometers and No. 9 illustrates the calculation of the molar heat of vaporization from the normal boiling point.

Part III presents the results of an exhaustive search of the literature for results on vapor-liquid equilibrium data published up to February 1957. The material is arranged in tabular form for easy reference and includes references to both binary and multicomponent systems. The authors state clearly that they have made no attempt to evaluate this data with respect to either accuracy or consistency.

In the opinion of this reviewer the authors have succeeded in the task of providing the chemist and chemical engineer concerned with distillation a theoretical and experimental work on vapor-liquid equilibrium together with a review of the literature of this subject. This book is comprehensive in scope but none the less thorough. Its thoroughness is attested by the 1232 literature references quoted. While the authors state that no previous knowledge of advanced thermodynamics is required of the reader, it seems only fair to say that readers unacquainted with this field would do well to consult one of the standard texts before attempting to apply the methods given. To conclude, it is believed that this advanced, though practical, treatise will be welcomed by English-speaking workers in the chemical industry dealing with the problems of distillation. (*Reviewed by J. W. Givens*)

GEAR SYMPOSIUM REPRINTS

American Society of Lubrication Engineers
84 East Randolph Street, Dept. GS
Chicago 1, Illinois

Name_____ **Title**_____

Company_____

Address_____

City_____ **State**_____

ASLE Members

Please send me the following preprints from the ASLE Gear Symposium (State number of copies desired in box)

☐ "Gear Lubrication—The Known and the Unknown" by Al Hundere, ALCOR, Inc.

☐ "The Gear Rig as an Oil Tester" by Earle A. Ryder, Consulting Engineer

☐ "The Effects of Lubricants on Gear Tooth Scuffing" by P. M. Ku and B. B. Baber, Southwest Research Institute

☐ "Recent Developments in the Lubrication of Heavy Duty Gearing" by G. P. Maurer, Falk Corporation

☐ "Efficiency of Involute Spur Gears" by E. E. Shipley, General Electric Co.

☐ "Wear in Heavily Loaded Lubricated Surfaces Subjected to Oscillating Motion" by J. F. Batter and F. E. Reed, Technical Operations, Inc.

☐ "A Laboratory Rating Method for EP Lubricants" by A. J. DeArdo and L. B. Sargent, Jr., Aluminum Co. of America

☐ "Analytical Study of Surface Loading and Sliding Velocity of Automotive Hypoid Gears" by D. L. Powell and H. R. Barton, Armour Research Foundation

☐ "Limited Slip Differentials" by L. J. O'Brien, Dana Corporation

☐ "Apparent Viscosity of Lubricant Films under Very Low Shear Rates" by E. K. Gatcombe, Prof. Mech. Eng., U.S.N.P.G. School, R. P. Hunnicutt, Dalmo Victor Co., and G. F. Kinney, Prof. Chem. Eng. U.S.N.P.G. School.

Lube Lines

by A. F. Brewer*

Start—Stop

Every piece of mechanical equipment must start and stop at some time or other. The greater the frequency of this cycle the more severe can be the potential effect upon wear between the various contact surfaces. This is an irrefutable fact. It can, however, be controlled by judicious choice of materials and lubrication. A homey example of start-stop service is presented by the everyday operation of the family automobile. Perhaps there are statistics which indicate the average number of such cycles. Even so, they can be no reliable indication of relative wear of, let us say, engine bearings, rings and cylinders. Mr. *A* might take off like a jack-rabbit before his oil pump barely starts to function. Mr. *B* might be more considerate of his car and more appreciative of the fact that cold starting in particular, requires a few turns of the pump to insure renewal of the necessary lubricating films on his engine parts.

"So what," says Mr. *A* "I'll trade in next year and let the next guy worry." Maybe that's another reason why he does not follow oil-change recommendations too closely.

Machinery builders must live with such people. That's where research came into the picture not too many years ago—cooperative research between the petroleum chemist, the mechanical engineer, the physicist and the designer. Some remarkable combinations of materials have resulted from this research —Aladdin's genii had nothing on modern technology.

Starting and stopping of machinery is not just a procedure of throwing a switch or turning a key in order to put a machine into or out of service. Sometimes it requires warm-up or cool-down procedure, regulation of circulating water or attention to the lubricating system. Sometimes there are warning indications of starved or faulty lubrication, such as the little red bullseye on the instrument panel of your late model car. In cases such as steel mill service where fabric bearings are involved and water is the predominating lubricant, a shot of auxiliary lubricating oil is necessary just before stopping in order to prevent shaft or roll neck rusting during standby. A typical example of starting procedure occurs where vertical stands of rolls are involved. After a period of inaction, the weight of the rolls could force out most of the existing lubricating film from the clearance spaces of the lower roll necks. Here on starting it is most essential to renew this film before turning over. An auxiliary oil pump can be used for this purpose.

Of necessity we are dealing with steel where shafting, journals or roll necks are involved. Consequently, rust and corrosion problems must be considered along with problems of wear. Bearing materials (and sometimes gears) are a different matter. They may be metallic, laminated fabric phenolic-base, nylon, or one of the fluorocarbon resins such as "Teflon." More recently the latter has been used as rings in compressor and hydraulic cylinders.[1] Some bearing materials have more "built-in" lubricating ability than others, notably the high lead-base babbitts, some of the porous metallic bearing materials, or the plastic "Teflon."

Research in the field of non-metallic materials has produced some remarkable aids or even replacements for conventional lubricants. Likewise research in the field of chemical additives has produced equally remarkable fortifying agents which materially enhance the lubricating and protective ability of conventional oils and greases. In fact, this age of additives and non-metallics is a most important age to management. The modern industrialist who is concerned with design, production or operation of machinery should regard knowledge of what is going on in this field as a positive *must* for his people.

Fortunately the progressive lubrication engineer has anticipated this *must*. Through his association with the petroleum, chemical, metals and plastics industries he is up-to-date as to the most modern ways and means of maintaining most effective lubrication. From the time the starting switch is thrown till the machine finally is secured, his is the ultimate responsibility for selection, handling, application and conservation of lubricants. His insurance value to management is inestimable.

* Consultant and author of "Basic Lubrication Practices."

[1] Du Pont Magazine, August-September 1958.

Where heat is a problem-use

BARAGEL*

for top performance!

Greases made with BARAGEL give top performance on equipment such as this high temperature rotary calciner where extreme temperatures are a constant problem.

BAROID

BAROID CHEMICALS, INC.

A SUBSIDIARY OF NATIONAL LEAD COMPANY

1809 SOUTH COAST LIFE BLDG. HOUSTON 2, TEXAS

*Trademark of National Lead Co.

Vol. 15, No. 1

Lubrication Engineering

DID YOU RESOLVE . . . ?

Not that we mean to pry, but we would like to sneak a look at each and every member's New Year's resolutions. We'd skip over all the ones like "I will limit myself to two lunch-time martinis," because we'd limit our search to only one resolution—the one that says "I will attend the 1959 Annual Meeting."

Perhaps putting it on a resolution-type basis makes the Annual Meeting sound as though it's something that falls under the heading of "duty." Yet it's far more than that. This year's meeting at Buffalo is vital to all those who realize the far-reaching consequences of the space age upon which we are now embarked. The role of the lubrication engineer in this new era is an important one, one which requires the knowledge which can best be gained from the kind of papers which will be presented at this year's Annual Meeting.

So if you haven't already done so, make your plans now to be at Buffalo's Hotel Statler on April 21, 22 and 23 for a meeting that will prove of value to you for years to come.

J. D. Lykins, President

Economics of Rolling-Contact Bearing Inspection in Industrial Plants

More than 10 per cent of new bearings tested over a four-year period contained defects such as nicked balls. Appropriate test equipment brought about a substantial savings in the rolling contact bearing inspection program at the author's plant.

*by Cort L. Miller**

A few years ago, the question was asked, "Are used ball bearings worth saving?" Experience has proved that the answer is an emphatic yes. Approximately 35,000 used bearings are cleaned and tested each year with two out of three being reinstalled or returned to stock for future use. These bearings come from various machines that are being cleaned, repaired, or overhauled for reasons other than actual bearing failure. One of the major problems has always been whether to re-use old bearings or to install new ones. The investigation of this problem resulted in the establishment of the Bearing Center where bearing quality could be determined by instruments instead of by opinion.

WHY ESTABLISH A BEARING CENTER?

Discarding used bearings and installing new ones to prevent possible machine shut-downs appeared to be a practice meriting a thorough study. The first requirement was a test method to determine accurately the mechanical condition of a bearing. During the investigation of this problem, it was determined that a used bearing is often better than a new one simply because it has already proved its ability to run. In addition, approximately 50 per cent of the used bearings were as good or better than new. The Bearing Center was justified by savings realized from the recovery of used bearings.

The following are actual savings for one year from testing used bearings:

Bearings Tested	34,371
Bearings Returned to Stock	21,432
Per Cent Bearings Returned to Stock	62.4%
Cost of Equivalent New Bearings @ $1.75 ea. Av.	$37,500
Cost of Cleaning and Testing Bearings @ $.25 ea.	$ 8,600
Savings	$28,900

Obviously every bearing that is removed from a machine is not a good candidate for cleaning and testing. For example, if a bearing has a broken retainer or race, has experienced excessive corrosion, or is known to be damaged when disassembled, it should be discarded.

THE BEARING CENTER

A Bearing Center performs three separate functions: cleaning, testing, and packaging. It should be in a quiet, vibration-free area and consist of two rooms —one for cleaning and wrapping, and another for testing.

Cleaning. Cleaning involves removal of most of the grease, dirt and varnish in a precleaning tank followed by a final rinse in an ultrasonic vapor degreaser. Figure 1 is a view of the Bearing Center's complete cleaning facilities.

The tank on the extreme right contains a rust inhibited oil into which bearings are dipped immediately after final cleaning. The middle tank is the precleaner used for the bulk removal of dirt. It contains a high flash solvent-alkali mixture which is heated to 130F. At the far left is an ultrasonic vapor degreaser which is the mainstay of our cleaning procedure. The unit consists of a standard vapor degreaser with the ultrasonics added to one side. The working volume is 18 in. x 21 in. x 12 in. deep. A 1.2 K.W. generator mounted in the wall supplies energy to the barium titanate transducers.

Experience has shown that ultrasonics does an excellent job of completely cleaning assembled bearings, with no evidence of brinelling. The only word of caution is that a cleaner of sufficient size be purchased to handle more than just bearings. Undoubtedly, once such a unit is available, many other uses will be found for it, such as cleaning roller chains, hydraulic valves, and sub-assemblies. The size described above is the minimum recommended. The complete unit purchase price is in the $3,000 range.

The ultrasonic cleaner has its limitations. It is not suited for removal of large quantities of dirt and

* Eastman Kodak Company, Rochester, New York.

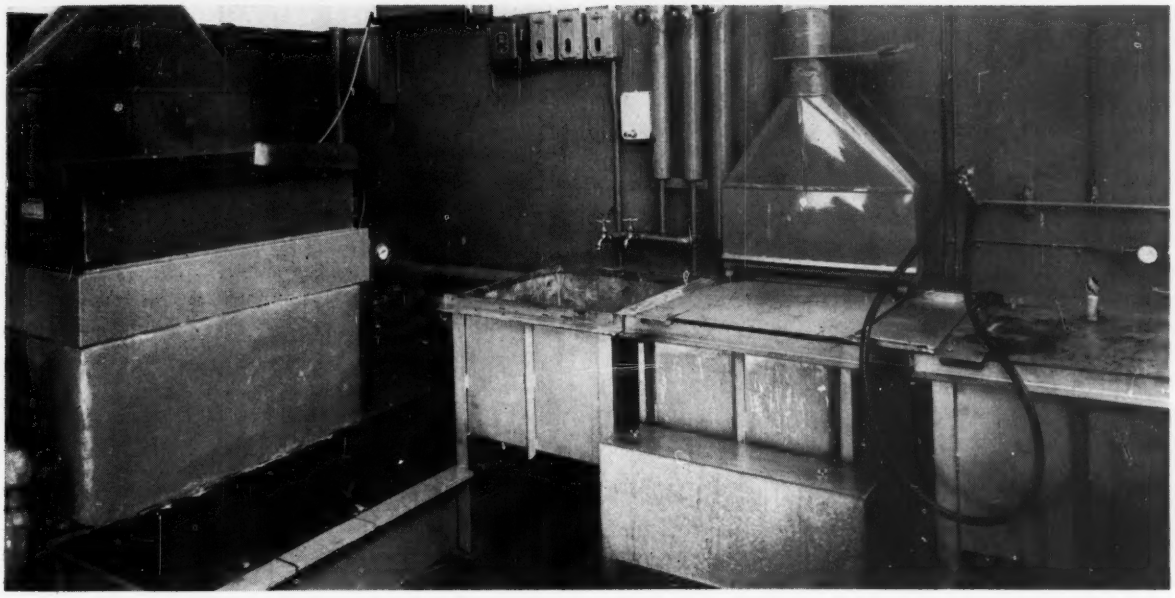


Figure 1. Bearing Center's cleaning facilities.

grease. Its main purpose is to clean metal parts when it is beneficial to remove the last trace of dirt such as lapping compounds or any dirt trapped in blind holes by a binder such as oil or grease. Rust, paint, or any coating bonded or hardened onto a metal surface will not be removed unless it is soluble in the solution used in the cleaner.

Testing. The testing of both new and used bearings employs the same method. The various tests can be classified into two categories, physical tests and dynamic tests.

Physical tests consist of checking bearing dimensions such as bore, outside diameter and radial clearance. These dimensions are fixed by the Anti-Friction Bearing Manufacturers Association (AFBMA), and all bearing manufacturers adhere to them closely. Relatively simple and appropriate gauges for checking dimensions are available. The Bearing Center concerns itself with these tests in special cases only.

The main interest is in the dynamic test to determine noise in bearings caused by brinelled or rough races, damaged balls, etc. In order to perform this test, a sound-proof area is necessary. A special test spindle and a trained operator are the other two requirements. Figure 2 shows a view of the test room. It is of frame construction with fibreglas insulation for sound deadening between two sheets of cement-asbestos board. Acoustic tile is used to cover the inside wall.

Recently soundproof booths have become available from various sources at a reasonable price. Rather than build a room, these booths offer a better, cheaper method of obtaining a soundproof area.

The noise test spindle is mounted inside the sound-proof room. Essentially, the spindle is very similar to a bench lathe. It has a head stock in which plugs are mounted for the various size bearings. The tail stock accommodates suitable plates which apply a thrust load to the outer race through a lever arrangement. The test spindle and bearing adapters are also shown in Figure 2. The spindle is inside the room, while the coupling and variable-speed motor are outside. This prevents motor noise from interfering with testing.

Both motor and spindle run on precision sleeve bearings. The over-all misalignment between the mo-

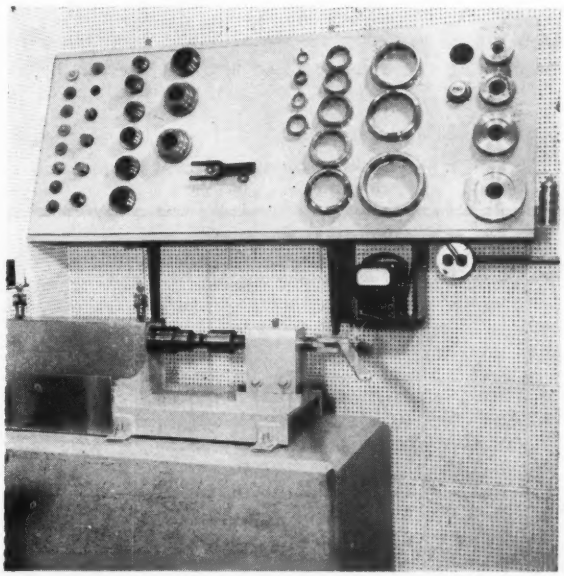


Figure 2. Noise-test spindle in soundproof room.

tor and tail stock is not more than 0.0003 inches. The motor and spindle are mounted on a concrete block which is isolated from the building by vibration dampers. The mass of the concrete dampens any vibration caused by the coupling or motor. The complete machine is dynamically balanced. Ideally, the spindle should be noiseless and vibrationless. The operator places a bearing on the head stock and rotates it at the appropriate speed. This varies from 1,200 RPM to 3,600 RPM depending on bearing size. He then engages the tail stock against the outer race of the bearing which is stationary. By applying a thrust load first on one side and then on the opposite side of the bearing, all race surfaces come in contact with the rotating balls. From the noise the bearing makes and the vibration through the tail stock lever, the condition of the bearing is determined. For example, a defective ball will make a characteristic noise that will come and go as the defect rotates in and out of the ball path. Brinelling, damaged races and dirt all make distinctive sounds. This does not mean that because a bearing makes noise it is defective. Certain types of retainers and styles of bearings are inherently noisy. A highly trained operator can usually determine what the defect is. This testing procedure depends on a trained operator and is subject to human error; however, it is still the most reliable and universally used by the bearing manufacturers.

Considerable work has been done to measure bearing noises with instruments, but, to date, no acceptable method has been achieved. Several instruments have been helpful to the operator but have not resulted in reproductible numerical values to indicate bearing quality.

Table 1 shows the results of an investigation made on the noise test spindle using two types of instruments. The first was a sound-level meter measuring decibels on three frequency scales. The A and B scale adjust the frequency response of the instrument to match that of the human ear, and the C scale is flat between 20 to 10,000 cps. (See American Standard Association Frequency Response Curves). The second instrument was a vibration meter measuring displacement in micro-inches, velocity in in./sec and acceleration in in./sec.^{2} A group of 202 bearings containing both good bearings and those with known defects was selected by the operator. These are numbered 1 through 9 with the defect listed after each bearing. The first tests were made with the sound-level meter.

The A scale shows fair correlation but the spread between good and bad is only 5 decibels in one case. The variation in mounting of the microphone makes it difficult to reach agreement between various test spindles. The other scales, B & C, show no correlation.

The next test was made with the vibration meter. A crystal pick-up was placed on the outer race of the bearing as it was being rotated on the spindle. From Table 1 it is readily apparent that the displacement and velocity show no correlation with the noise test. However, acceleration shows remarkably good correlation with the noise test. Good bearings were in the range of 30 to 40 in./sec^2; defective ones 60 in./sec^2 or above.

In view of the foregoing tests, further investigation was undertaken on other bearings with similar results. Figure 3 shows the acceleration curves of the two other groups of bearings.

The top row shows the acceleration curve of two 204 single shield bearings. The curve on the left is of a good bearing; the curve on the right shows a bearing containing a defective ball. The bottom row shows the acceleration curves of three 206 bearings. The left curve is that of a good bearing; the middle curve represents a defective ball and brinell marks; the right curve represents a defective race. These curves show a marked difference between good bearings and

TABLE 1. Sound Level and Vibration Measurements Vs. Bearing Defect

BRG. NO.	DEFECT	SOUND LEVEL METER DECIBELS FREQUENCY SCALE A	B	C	VIBRATION METER DISP. MICRO INCHES	VEL. IN/SEC	ACCEL. IN/SEC^2
0	0	46-47	59-61	69-70	100-200	.008	4.5-5.0
1	Brinelled	60	63-64	69-70	260	.08-.1	160-180
2	Race	53	40-60	69-70	270-280	.04	60-80
3	Ball	57-60	61-62	69-70	250	.04-.05	90-110
4	Good	48	59-61	69-70	350	.05	28-30
5	Ball	61	66	71	330	.08-.09	270
6	Good						35-38
7	Good						37
8	Good						32
9	Ball						80

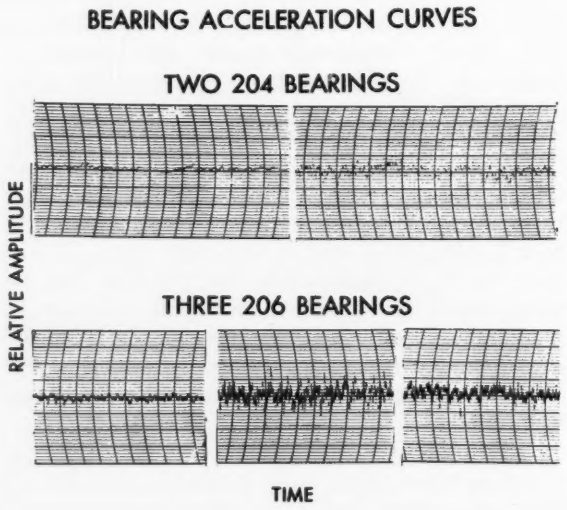


Figure 3. Bearing acceleration curves.

ones containing defects. However, application of this method of testing to production work is not without its problems. The type of transducer, its mounting, the meter and its calibration all have to be standardized before any reproducible results can be obtained. A current investigation is being made with a ceramic transducer mounted in the handle of the test spindle as shown in Figure 4. The meter is calibrated in g^s and has a full scale range of .01, .5, 1.0, 5 and 10 g^s.

At present the noise test and accelerometer both are aimed toward sorting out obvious defects. As more experience is gained, it is hoped to be able to establish standards for general noise level of each size and type of bearing.

Packaging. After a bearing is cleaned and tested, it has to be packaged properly for stock. One method is to pack the bearing with a good grade of ball bearing grease, wrap it in red acid-free wax paper or polyethylene coated paper and box it. If bearings are wrapped in rolls, it is probable that the roll will be opened later to obtain one or two bearings, thus leaving the rest exposed. Therefore, all bearings are boxed individually. All used bearings are identified by the date etched on the face of the outer race. By doing this, a service record of the performance of all used bearings is available.

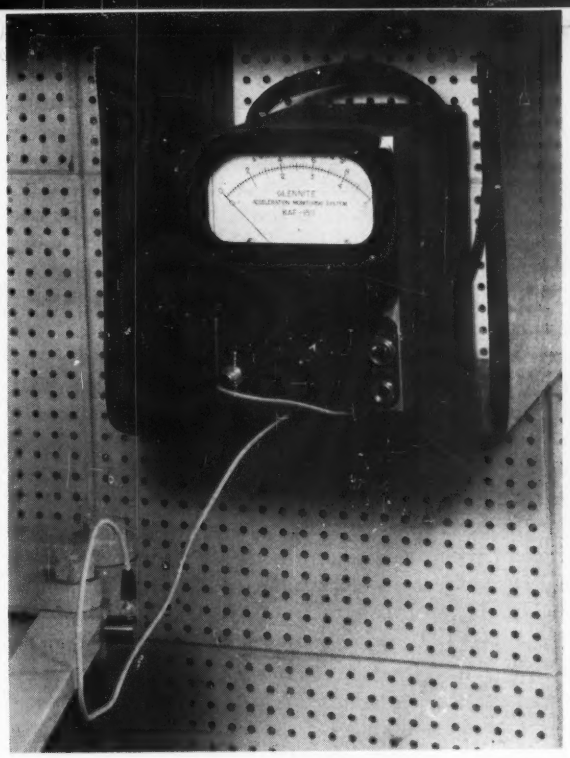


Figure 4. Accelerometer.

STOCKING BEARINGS

An efficient system for stocking bearings is another important part of the Bearing Center. Bearings stored for extended periods of time are subject to corrosion, false brinelling and grease deterioration. To prevent this, a central stock area was established to consolidate and adjust stocks so that a six-month turnover could be maintained. Stored bearings were collected throughout the plant and put in central stock. Duplication of bearings was quite noticeable. Not only did departments stock identical bearings, but they stocked them under several manufacturers' numbers. An interchangeability table was developed as illustrated in Table 2 so that any bearing, regardless of manufacturer, would have the same designation.

TABLE 2. BEARING INTERCHANGEABILITY—BEARING, BALL, SINGLE ROW, RADIAL, EXTRA SMALL

BASIC BRG. NO.	SHIELDING	DIMENSIONS BORE M.M.	O.D. M.M.	WIDTH M.M.	MANUFACTURERS A	B	C	D	EK STANDARD NUMBER
38	Open	8	22	7	A-8	B-8	C-8	D-8	492-2038-013
38	2 Shields	8	22	7	A-82	B-82	C-82	D-82	492-2038-213
38	2 Seals	8	22	7	A-84	B-84	C-84	D-84	492-2038-413
39	Open	9	26	8	A-9	B-9	C-9	D-9	492-2039-013
39	2 Shields	9	26	8	A-92	B-92	C-92	D-92	492-2039-213
39	2 Seals	9	26	8	A-94	B-94	C-94	D-94	492-2039-413
		BEARING, BALL, SINGLE ROW, RADIAL, LIGHT							
					A	B	C	D	
200	Open	10	30	9	A-2000	B-2000	C-2000	D-2000	492-2200-013
200	1 Shield	10	30	9	A-2001	B-2001	C-2001	D-2001	492-2200-113
200	2 Shields	10	30	9	A-2002	B-2002	C-2002	D-2002	492-2200-213
200	2 Seals	10	30	9	A-2004	B-2004	C-2004	D-2004	492-2200-413
201	Open	12	32	10	A-2010	B-2010	C-2010	D-2010	492-2201-013
201	1 Shield	12	32	10	A-2011	B-2011	C-2011	D-2011	492-2201-113
201	2 Shields	12	32	10	A-2012	B-2012	C-2012	D-2012	492-2201-213
201	1 Seal	12	32	10	A-2013	B-2013	C-2013	D-2013	492-2201-313
201	2 Seals	12	32	10	A-2014	B-2014	C-2014	D-2014	492-2201-413

The table gives a basic description of the bearing, its dimensions and the various manufacturers' designations. The Standards Number appears at the far right and is the number used to identify the bearing. The Standards Number is the only identification appearing on the bearing box. Each digit in this number has a meaning which serves to describe the bearing. The first three digits are a general classification: single row (492), double row (493). The next four digits classify the bearing by type and size. For example: a metric series 201 bearing would have a 2201 for the middle four digits. The last three digits specify the type of shields or seals, the tolerances and other special features. For example: a double-shielded, ABEC 1 regular Conrad type bearing would have 213 for the last three digits. By affixing a meaning to each digit or group of digits in the bearing number, a logical system was developed that made bearings easy to code and to locate.

In the process of the consolidation, it was decided to clean and test the existing stock of some 10,000 bearings. It was found that 15 per cent of these bearings were unsuitable for use, primarily due to rust spots and brinelling. If these 1,500 defective bearings had been put in service, a premature bearing failure would have resulted. The average bearing change costs $30. Thus, by not installing this group of 1,500 defective bearings, an expenditure of $45,000 was averted.

NEW BEARING TESTING

The testing of the stock inventory of bearings aroused interest regarding the condition of new bearings. It was decided to run a statistical analysis of new bearings to see if any significant defects would be found through use of noise test equipment. The analysis included various sizes, styles and makes of bearings. The results of these tests merely confirmed the AFBMA rating-life curve. This curve indicates that approximately ten per cent of a group of apparently identical bearings will fail before their rated life.

These tests, which revealed that 11.6 per cent of bearings inspected had some imperfection, picked up such things as imperfect balls, rough or brinelled races, or loose retainers. Borderline cases were not considered important. Since it would greatly increase the cost of bearings if manufacturers were to screen out all noisy bearings, the importance of the degree of bearing imperfection varies with the critical requirements of the user. If requirements are critical, complete inspection before use will also serve to eliminate bearings, satisfactory in manufacture, which were subsequently damaged in shipment or handling in the user's own plant.

It appears that a satisfactory method of inspection might prove to be a means of eliminating the commonly recognized 10 per cent premature bearing failures. Some of the common causes to which early bearing failures are generally attributed are flaws in the metal, manufacturing imperfections, handling damage or storage deterioration. The noise test was not designed to determine metal flaws. However, it is felt that most of the rejected bearings resulted from the other reasons just mentioned. This means that bearings that fail before their rated life could be eliminated, except for those that fail due to hidden metal flaws.

In view of the above findings, it was concluded that if 35,000 bearings per year were used and 11.6 per cent ran less than their rated life, requiring a $30 bearing change, an expenditure of $121,800 per year for premature bearing failures could be eliminated. It was decided to test all of the incoming bearings. As a result of testing approximately 50,000 new bearings, an average of 10.6 per cent have been found to be substandard. The savings resulting from not using these bearings can be calculated as follows:

Bearings tested	35,000
Per cent rejected	10.6%
Total rejected bearings	3,710
Cost of replacement per bearing	$30
Cost of replacement (Total) ..	$111,300
Cost of testing 35,000 Brgs. @15¢ each.	5,250
Savings	$106,050

Besides realizing considerable savings by not installing these bearings and gaining more reliable equipment operation, another benefit would be derived from this testing program. Bearing failure can be caused by improper installation, dirt, etc., as well as by substandard bearings. Mechanics would be alerted to the fact that they can no longer blame an early bearing failure on a substandard bearing. As a result, they would be much more cautious when installing a bearing.

INVESTMENT VS. SAVINGS

The capital investment required to establish a Bearing Center as well as savings derived from it, will vary with the type of industry, local labor costs and type of test equipment. Table 3 shows the investment vs. savings figures based on the labor and material costs of the testing installation and savings based on processing 35,000 used bearings and testing 35,000 new bearings.

The Bearing Center was established as a result of savings made on used bearings. From Table 3 it may be seen that the capital investment could be over 45 per cent of the first year's savings on used bearings. Through expanding testing facilities to include new bearings, the savings would jump to over four and one-half times the original amount. The investment amounts to only one-tenth of the yearly savings. As new equipment and bearing knowledge is gained, it could be expected that further savings will be realized.

(*Cont. on page 27*)

Lubrication Problems in High-Speed Gears

*by Jack W. Dern**

ABSTRACT

This paper describes some of the design criteria for high-speed gears and a proven method of lubricating them. A test procedure for high-speed gear boxes is described, and the development program of two high-speed gear reducers is related, including a description of special design considerations.

One of the principle problems has been effective scavenging of lubricant. Devices for successfully scavenging high-speed gear boxes are discussed and the results of proper application described.

There are two measures of gear speed. The first and most universal measure of gear speed is revolutions per unit time, generally expressed as revolutions per minute. This is not a critical measurement of gear speed, but is actually an expression of frequency. The second and more definitive measure of gear speed is the pitch line velocity expressed in feet per minute.

Lubrication problems increase with gear speed. This article will be concerned primarily with the problems which have been encountered in developing two gear boxes to operate at pitch line velocities between 20,000 and 25,000 feet per minute, with shaft speeds ranging from 10,000 to 30,000 RPM. (See Figure 1.) These gear boxes were simple spur gear reductions transmitting approximately 2000 horsepower. The test stands built to test these gear boxes involved similar speeds but with only 100 to 200 horsepower.

GEAR DESIGN

Gears in general must be designed with bending and compressive strength adequate for the specific application. In modern practice, particularly for high speed gears, both bending and compressive strength is designed to satisfy specific fatigue life requirements.

For high speed gears, there are several other special design criteria. Two of these are frequently used to check a proposed design for (to coin a word) "lubrability," and to aid in choosing a proper lubricant.

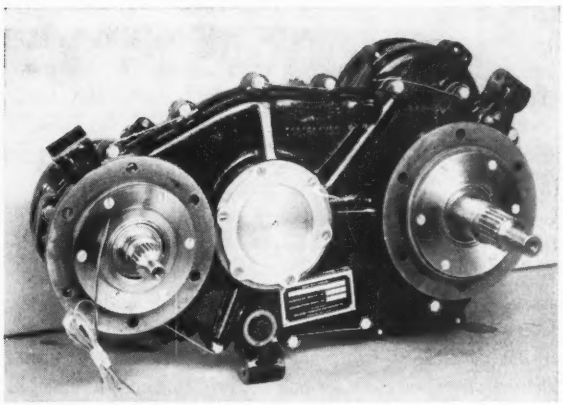


Figure 1. Typical aircraft-type high-speed gear reducer.

The first requirement is a satisfactory slide-sweep ratio as described by Tuplin (1).

The slide-sweep ratio is the ratio of the sliding velocity at the point of contact to the velocity of the point of contact across the surface in question. The design procedure used for high speed gears, in order to guarantee oil film stability, requires the slide-sweep ratio at the lowest point of single tooth contact and at the highest point of single tooth contact of the gears involved to be small, preferably less than 0.2. In order to choose a lubricant intelligently, the theoretical instantaneous temperature at the point of tooth contact is determined, again at both the lowest and highest points of single tooth contact. The Kelley-Blok Temperature Formula (2) is frequently used for determination of the theoretical instantaneous surface temperature. It is wise to choose a lubricant with a limiting temperature (see Table 1) at least 100 degrees greater than the highest computed temperature.

High speed gears generally require both high mechanical efficiency and good design efficiency still they are used most frequently for aircraft applications. Mechanical efficiency results in low power loss; thus, low heat generation. Mechanical efficiency can be determined anlytically with a fair degree of accuracy. Further, an excellent correlation between the results

* Gear Engineer, Steel Products Engineering Co., Division of Kelsey-Hayes Company, Springfield, Ohio.

Sponsored by the Gears and Gear Lubrication Committee of the American Society of Lubrication Engineers

Presented before the 13th Annual Meeting of the ASLE, April 24, 1958, at Cleveland, Ohio

TABLE 1. LIMITING DESIGN TEMPERATURES FOR GEAR LUBRICANTS

Petroleum—SAE 10	250F
—SAE 30	375F
—SAE 60	500F
—SAE 90 (Gear Lube)	600F
Synthetic—MIL-L-7808	600F
Compounded—SAE 30 plus EP	425F
—SAE 40 plus EP	500F

of efficiency computations, slide-sweep ratios and theoretical instantaneous surface temperatures has been shown; that is, gear sets with a higher theoretical efficiency had more desirable slide-sweep ratios and lower theoretical instantaneous surface temperatures.

Design efficiency may be described as obtaining the maximum mechanical efficiency in a minimum space configuration with a minimum of weight.

GEAR LUBRICANTS

Gear lubricants vary from the greases used for low speed intermittent drives such as actuators and hoists, through various oils to thin non-foaming synthetics used in high speed high temperature applications, such as gas turbines. Also, experiments have been conducted with one inert lubricant which, having a relatively high specific weight, caused much higher gear box temperatures due to the increase in energy required to accelerate the lubricant to gear and bearing speeds. The majority of the high speed gear boxes developed have been for use in conjunction with gas turbines; therefore, in may cases, the gear lubricant specified is gas turbine oil, per military specification MIL-L-7808. Fortunately, this has proved to be a good lubricant for high speed gears.

METHOD OF LUBRICATION

Most gear authorities agree that high speed gears must be lubricated on the leaving side of the mesh, as excessive lubricant between the gear teeth will result in high dynamic loads which leads to higher stress levels and earlier tooth failure. Actually, most of the oil is used for removing the heat generated by gear tooth action; lubricating on the leaving side of the mesh puts the oil, used here as a coolant, as close as possible to the heat source. Lubrication of the subject gear boxes has been in this manner, using one or two jets of .040 inch to .060 inch in diameter, spraying directly at the mesh. This size range has proved to have good non-clogging characteristics, is not too difficult to produce, and provides good oil stream control.

For gears running at speeds above 16,000 to 18,000 feet per minute, depending somewhat on face width and stress levels, more satisfactory results may be obtained by spraying oil radially into the teeth of both gears at a point as close as possible to the mesh (see Figure 2). The sprays are solid streams of lubricant. Oil mist lubrication was not used, as it is generally difficult to obtain compressed air for lubrication in aircraft type installations.

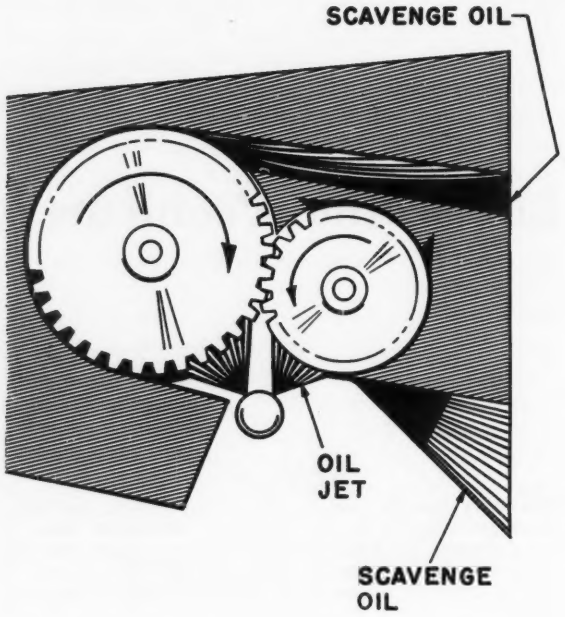


Figure 2. Lubrication and scavenging in a high-speed gearbox.

TEST PROCEDURE

The type of gearbox being discussed transmits high power at high speeds. It would be both difficult

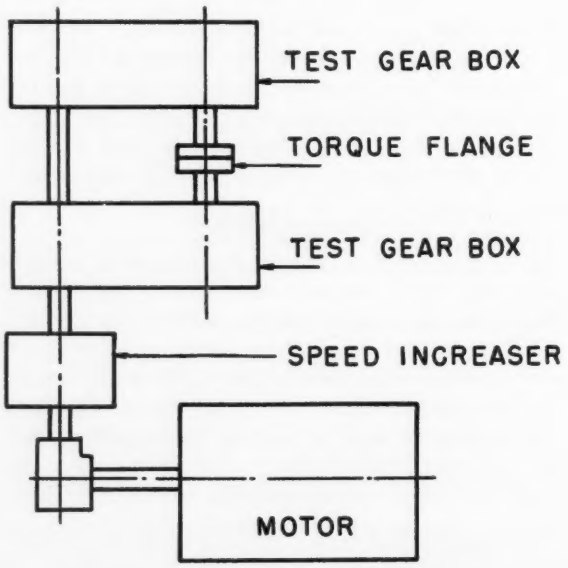


Figure 3. Typical torqued loop gear test arrangement.

and expensive to dissipate the power involved, so a simple torque loop system similar to the one shown in Figure 3 was used. In the figure, two basically identical gear boxes are shown, interconnected with a flanged torquing shaft and a solid shaft to close the torque loop.

The rated shaft torque is set in the flanged torquing shaft by means of spanner wrenches and the flanges locked in place. These gear boxes are then driven at rated speed by the electric motor and speed increaser gear box as shown. In the application diagrammed, a right angle drive was included in order that the gear boxes could be tested in their normal position, shaft vertical, with a standard electric motor.

A certain degree of caution must be exercised when testing in this manner, as one gear box is torqued in the normal running direction, but the other is torqued backward. This means that if the gear box is normally a speed reducer, one is acting as a speed increaser.

Gear boxes are generally less efficient when acting as speed increasers than speed reducers; higher instantaneous scoring temperatures will be encountered and more heat must be dissipated.

One gear failure has been experienced, due to excessive heat in a simple gear to idler to gear set. In this set the gears were identical in size and quality. The idler was of equal quality, but comparatively small, so that there was effectively one speed reduction and one speed increase involved in the train. All the gears were carburized, hardened and ground. In the failure, the gear driving the idler was badly discolored, and showed evidence of scoring and of metal having been displaced by flowing under pressure. The driven gear, although somewhat discolored, showed negligible amounts of scoring, and was considered acceptable for use in further testing. The idler showed indications of severe hot working.

To date, this type of testing has proved very satisfactory. Tests have shown that no appreciable load change occurs when gear loops are statically torqued, then the torqued loops accelerated to normal operating speeds. However, this type of testing is applicable only to units using rolling-contact bearings; journal bearings tested to date have proved unsatisfactory for dry starts under high loads with the rapid accelerations required. It would be desirable to torque the loop after full speed is attained, but this generally results in a very expensive test set-up which is often not justified.

DEVELOPMENT OF HIGH SPEED GEAR BOX NO. 1

The first tests of a gear box designed for high speed operation were simply no-load functional tests at reduced speed. The speeds developed were in the order of 10,000 to 12,000 feet per minute. These tests, performed before the test stand was completed, were very successful; operation was smooth, lubrication was satisfactory, oil was completely scavenged from the box.

Shortly after this, late in 1955, the first high speed gear test was made. It was a complete . . . failure! Although no external load was applied, the motor stalled before bringing the gearbox to rated speed. Disassembly showed the box was completely full of oil. Apparently, the high speed gears acted as pumps, without an outlet, building up an appreciable head. Disc friction, gear blank in oil, was another major factor. Designs which have specifically avoided these conditions have proved very successful.

Other gear box manufacturers encountered this same problem at about the same time.

The oil pump used in this gear box was a two element unit; the pressure pump had a rated capacity of three gallons per minute, the scavenge pump had a rated capacity of six gallons per minute.

Tests were run in which a portion of the oil from the pressure pump to the gear box was bypassed in order that the effects of reduced oil flow could be studied. With 16.3% of the oil bypassing the gear box, a successful no-load run was made. Other tests were run with 49% and 55.5% of the oil bypassing the gear box. Figure 4 shows comparative results of these tests. A typical bearing race temperature is plotted against time for the three different oil flows. Curve 1, for 16.3% bypass oil, shows a temperature of 315F at 60 seconds after start. Curve 2, for 49% bypass oil, shows a temperature of 260F at 60 seconds after start. Curve 3 for 55.5% bypass oil, shows a temperature of 180°F at 120 seconds after start. Under the conditions of Curve 1, the motor drew approximately 100% of rated current; under the conditions of Curve 2, it drew approximately 58% of rated current, and under the conditions of Curve 3, approximately 36%. From this, it might be concluded optimum operation could be obtained with no oil; obviously, gear tooth scor-

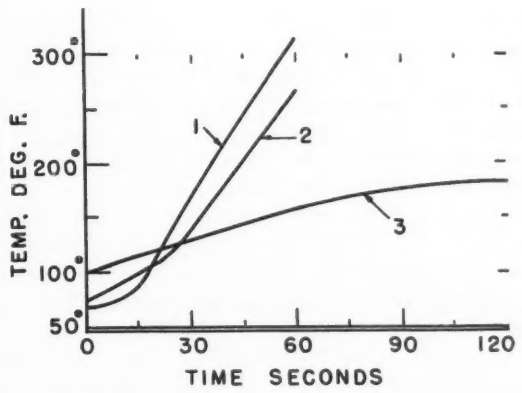


Figure 4. Bearing temperature curves.

ing would soon occur and bearing retainers would fail, due to lack of cooling.

The size of the scavenge openings was increased and scoops and baffles were placed to direct the oil flow into the scavenge openings, rather than depending solely on gravity. These changes resulted in a dependable, efficient gear box; mechanical efficiency at rated load and speed was approximately 98.4% in this two mesh speed reducer. Oil flow remained at rated pump capacity.

Late in the development program one of the gear boxes was tested with a special inert lubricant fortified with silicone. This material had a much higher specific weight than the MIL-L-7808 we had been using. While the unit did function satisfactorily with the heavier lubricant, the temperature rise was approximately 200% of the temperature rise experienced with the MIL-L-7808.

DEVELOPMENT OF HIGH SPEED GEAR BOX NO. 2

In designing a second gear box of just slightly higher speed than the first, and transmitting approximately 20% more power through three meshes instead of two, a specific attempt was made to eliminate the scavenge problem encountered in the first design. Scavenged oil from both gears and bearings was directed into passages which fed the oil into the scavenge inlet of the pump. This utilization of kinetic energy of the oil was expected to result in an efficient, cool-running gear box.

One gear was used as a pump. Clearance between the outside diameter of the gear and the housing and between the sides of the gear rim and the housing was limited to between 0.030 and 0.060 inch. The oil was thus trapped for approximately 210° of gear rotation before being emptied into a trough which fed the scavenge pump. Entrance to the trough was tangential to the outside diameter of the gear. See Figure 2.

At other locations the major portion of the oil was stripped from the gears approximately 15° of gear rotation after the oil jet. This being the major portion of the oil, it was directed into passages leading to the scavenge pump inlet. In order to remove as much as possible of the oil remaining on the gears, gashes were placed in the closely surrounding housing, sloped at approximately 30° from the vertical (gear shafts were vertical), so that oil entering the gashes would be directed down, away from the gears. The gashes are illustrated in Figures 5 and 6.

While it is not specifically the subject matter of the paper, the method of lubricating the bearings in these gear boxes should be mentioned. All the bearings were precision rolling-contact bearings; ball bearings for thrust, roller bearings for radial loads. They were all lubricated on one side only by a series of oil jets directed at the cage near the inner race. Oil slingers were provided on both sides of all bearings, and again the kinetic energy of the oil was utilized to carry it from the collector rings through scavenge ports toward the scavenge pump inlet. See Figure 7.

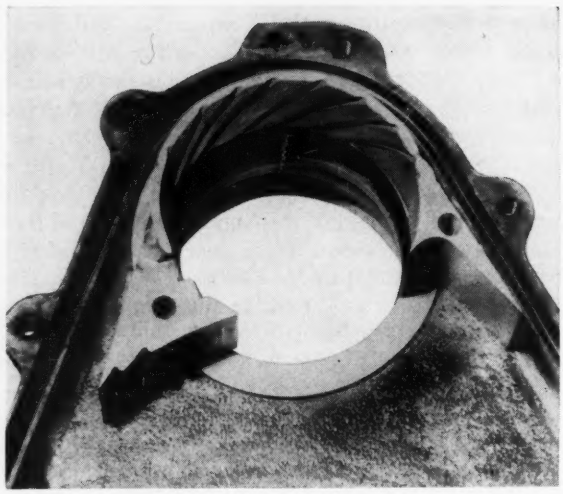


Figure 5. Installation of stripper casting with helical gashes in Type 1 gear box.

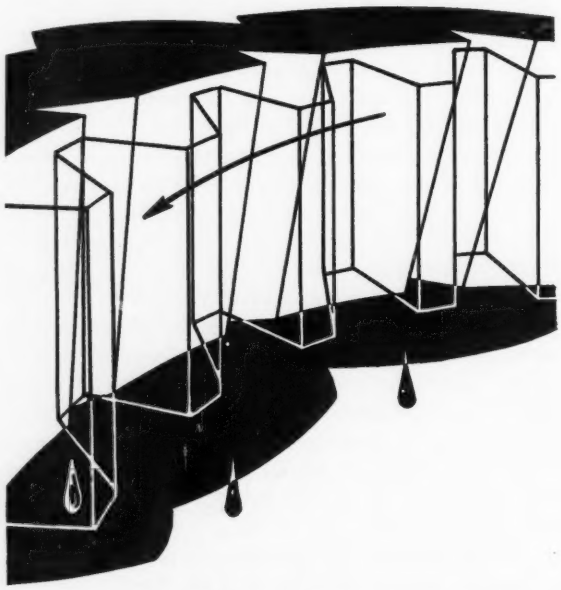


Figure 6. Operation of gear near housing with helical gashes.

No problems whatever were encountered in testing this second design. However, during one test, an oil line failed and one box was operated for about a half a minute with no lubrication. There was no appreciable bearing temperature change during this period and the drive motor current dropped slightly. An examination after this test showed absolutely no damage to either gears or bearings, and a light oil film remained on the parts. Undoubtedly, failure would have occurred soon after the oil film wore off.

The mechanical efficiency of this gear box at rated load and speed was estimated to be 99.4%, based on the same assumptions used in estimating the efficiency of the first gear box.

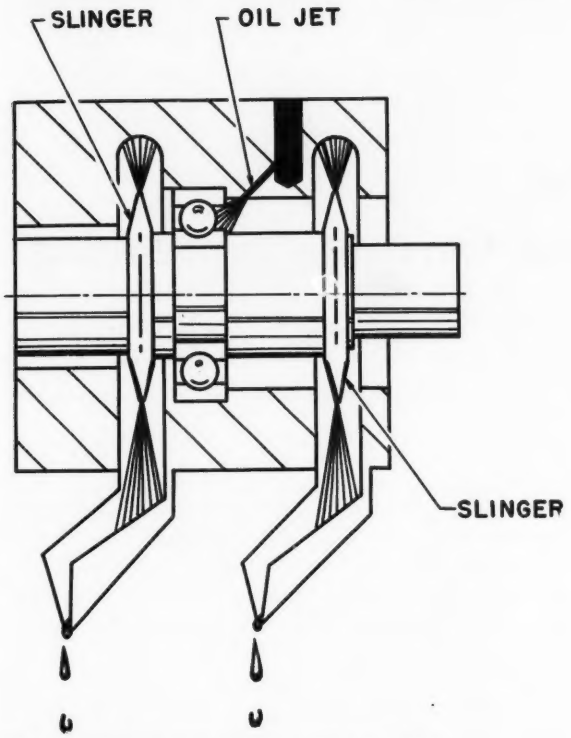


Figure 7. Typical high-speed bearing lubrication.

CONCLUSIONS

The principle conclusions which are to be drawn from this investigation, then, are that excessive quantities of oil should be avoided and that the scavenging of the oil should be controlled. The methods outlined use the kinetic energy of the oil leaving high speed gears to aid in scavenging the oil. It is believed that this is the proper approach in developing efficient high speed gear drives. These principles should hold true for gears operating at higher speeds, and are applicable to a proportionately lesser degree, for gears operating at lower speeds. The procedures outlined are not, however, the only ways for controlling scavenge oil. Some gear boxes have been developed in which the high kinetic energy of the oil is simply dissipated by forcing the oil through a fine wire mesh.

There was in the author's office, until his recent retirement, an engineer closely associated with aircraft power plants, accessory drives and associated equipment since the early days of the Wright brothers, Mr. Lawrence C. Rausenberger. On more than one occasion, he was heard to say "If you're got gears going real fast, they just want to smell the oil." This statement summarizes the philosophy of the author very well.

BIBLIOGRAPHY

(1) Tuplin, W. A., "Gear-Tooth Lubrication," Machine Design, August 1954, pp. 125-131.

(2) Kelley, B. W., "A New Look at the Scoring Phenomena of Gears," SAE Transactions, Volume 61, 1953, pp. 175-188.

Bearing Inspection in Industrial Plants

(Cont. from p. 22)

SUMMARY

The testing of new and used rolling-contact bearings in industrial plants can result in substantial savings. These savings can be realized only through the use of proper cleaning and testing facilities. The most satisfactory cleaning method found to date has been by the use of an ultrasonic vapor degreaser. Testing should be aimed at finding physical defects rather than dimensional testing. This type of testing depends on a noise test spindle with a trained operator interpreting bearing quality by ear. Tests conducted with noise level and vibration measuring equipment indicate that it is possible to affix a numerical value to bearing quality by means of a vibration meter, measuring acceleration. Establishment of an over-all plant bearing program can pay large dividends. The program should be tailored to the individual plant needs and developed in a systematic manner.

TABLE 3. INVESTMENT VS. SAVINGS

INVESTMENT		SAVINGS	
Cleaning Facilities:			
Room Construction	$ 1,500	Used Bearings	$ 28,900
Preclean Tanks	500	New Bearings	106,050
Ultrasonic Cleaner	3,000		
Installation	700	Total Yearly	$134,950
Testing Equipment:			
Soundproof Room	$ 2,500		
Test Spindle (Installed)	3,000		
Operator Training	500		
Vibration Meter (Optional)	1,500		
Miscellaneous:			
Wrapping and Etching Equipment	$ 400		
Total Investment	$13,600		

ATTACH THIS COUPON to a 3-cent postcard and obtain information on exhibit areas of the 1959 ASLE Annual Meeting

ASLE
84 E. Randolph St.
Chicago 1, Ill.

Gentlemen:

Please send me the Exhibit Brochure on the 1959 Annual Meeting by return mail.

My name _____

Company _____

Position _____

Address _____

City _____ Zone ____ State _____

The Causes and the Control of Electrical Currents in Bearings

*by J. Boyd and H. N. Kaufman**

ABSTRACT

When bearings become damaged in service, the question often arises as to whether the damage was due to electrical current. The damage caused by electrical currents may be negligible or may be catastrophic. Such currents may occur from several sources: 1) A bearing may carry current as a necessary part of an electrical circuit; 2) the current may be self-induced as a result of the design characteristics of the machine, or 3) the current may result from an electrostatic phenomena. This article describes the various sources of electrical current, the damage resulting from such currents, and the methods by which the damage may be reduced or eliminated.

INTRODUCTION

Normally, bearings are not expected to carry current, yet there are many instances in which they are called upon to do so. Sometimes this is by plan, often it is by accident. In either case, there would be no cause for concern except that the passage of current can, under certain conditions, result in bearing damage.

Although numerous articles have been written which deal with bearing currents, the subject ordinarily is not well understood. It is the purpose of this article to summarize the existing information showing 1) how the damage caused by the presence of such currents can be recognized, 2) how the currents themselves originate, 3) how the tendency for the formation of currents can be detected and 4) how the damage caused by such currents can be eliminated or controlled.

DAMAGE PRODUCED BY BEARING CURRENTS

Although other effects are sometimes present, the principal damage caused by bearing currents is due to sparking between the bearing and the journal surfaces or between the balls and the races, depending upon the type of bearing involved. High voltage is not necessary for sparking to take place and damage can occur at potentials well below one volt. The main consequence of sparking is pitting of the surfaces. This results in wear due to the removal of fused metal particles, but the roughening of the surfaces caused by pitting also produces wear by purely mechanical means. A further consequence of sparking is the danger of deterioration of the lubricant and the possible contamination of the lubricant and the lubricating system by spark debris.

In some cases, heating of the parts due to the passage of current may be important since the heating may result in damage to the bearing or the lubricant.

RECOGNIZING DAMAGE DUE TO BEARING CURRENTS

The damage caused by pitting due to bearing currents can vary greatly in extent as may be seen from Figures 1, 1*a*, 1*b*, 2, 3 and 4.

Figure 1 is a full size photo of a thrust bearing pad in which pitting is scarcely detectable as a light, frosted area. The same pad is also shown at 15x in Figure 1*a* and 25x in Figure 1*b*. The individual pits are too small to be seen except in a microscope. They average about 0.001 in. in diameter, which is much smaller than many of the surface scratches.

Figure 2 shows a pitted area from a large motor sleeve bearing. In this case the individual pits are about 0.0025 in. in diameter and can be readily detected with a low power magnifier.

Figure 3 shows a portion of a sleeve bearing pitted by high current. These pits can easily be seen by the unaided eye and range from 0.008 in. to about 0.010 in. in diameter.

Figure 4 shows a portion of the outer race of a ball bearing pitted by a relatively high bearing current. The pits are about 0.008 in. in diameter.

Regardless of their size, the pits produced by bearing currents have a characteristic appearance which aids in establishing their origin. Their most striking feature is that the bottoms of the pits are rounded and have the smooth, shiny appearance of having been melted. This can easily be seen in Figure 3.

Initially, each pit is a separate crater, more or

* Westinghouse Research Laboratories, Beulah Road, Churchill Borough, Pittsburgh 35, Pa.

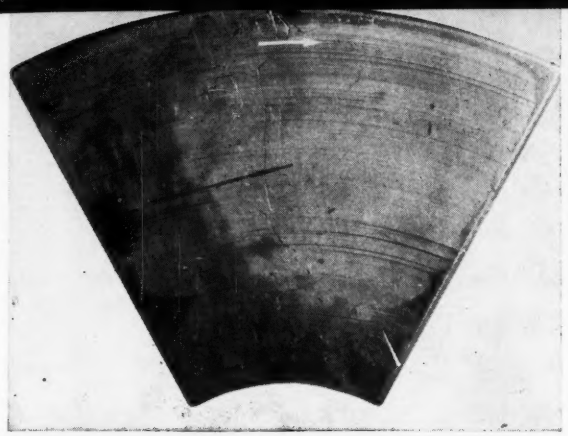


Figure 1 —Electrical pitting in a tin base babbitt thrust bearing pad, 3/5 full size
(Arrow shows direction of motion of runner)

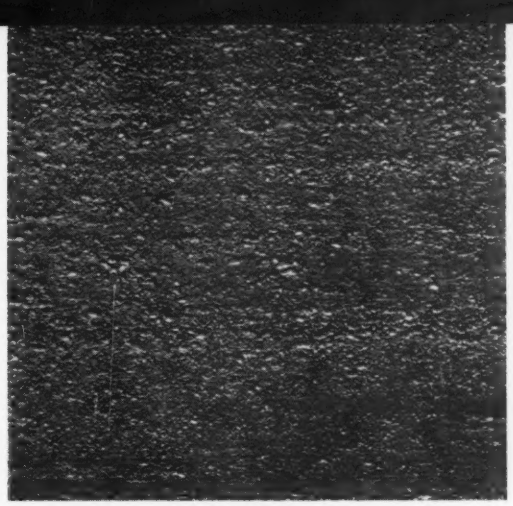


Figure 2 —Electrical pitting in lead base babbitt of a large motor bearing, 15x

Figure 1*a*—Portion of pad shown in Figure 1 enlarged 15x

Figure 3 —Electrical pitting in a tin base babbitt sleeve bearing, 15x
(Arrow shows direction of motion of journal)

Figure 1*b*—Portion of pad shown in Figure 1 enlarged 25x

Figure 4 —Electrical pitting on the inner raceway of a ball bearing, 15x

less circular in shape, similar to those of Figure 3. As the process continues, the pits begin to overlap, tending to destroy the clear evidence of their origin. However, if one surveys the periphery of the pitted area thoroughly, it will generally be possible to find isolated pits having the tell-tale crater-like appearance. Also, if one experiments with the location of the light source in areas where the pits have overlapped, electrical pits can usually be detected by the reflection from their smooth, melted bottoms.

In attempting to determine whether or not pits are of electrical origin, one must be cautious not to be misled by other types of pitting such as that caused by corrosion or by foreign particles. Figure 5 shows corrosive pits in a lead babbitt bearing. Such pits can usually be distinguished by their irregular form and their dull appearance. Figure 6 shows pits in a tin babbitt bearing produced by foreign particles. These pits are almost invariably accompanied by circumferential scratches. Frequently the pits have smooth bottoms but ordinarily they do not have the melted appearance of electrical pits. Often a series of pits of identical shape but of irregular outline will be spaced at regular intervals circumferentially over a portion of the bearing. This is unmistakable evidence of pitting due to foreign particles.

If electrical pits in a bearing become disfigured by wiping, foreign particles, etc., it may be possible to establish the fact that electrical pitting was involved by studying the journal surface. Electrical pits on the journal are usually considerably smaller than those on the bearing, but since the journal is generally harder than the bearing, electrical pits in the former are not as readily eradicated. Figure 7 shows a bearing containing electrical pits on which wiping has been superimposed, and Figure 8 shows the appearance of the corresponding journal following pitting and wiping.

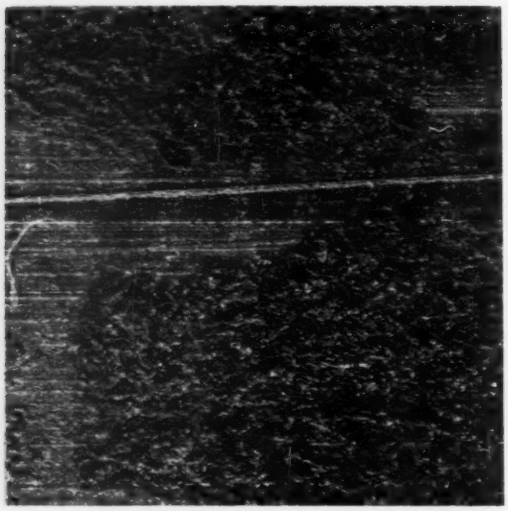


Figure 5 —Corrosive pitting in a large lead base babbitt motor bearing, 15x

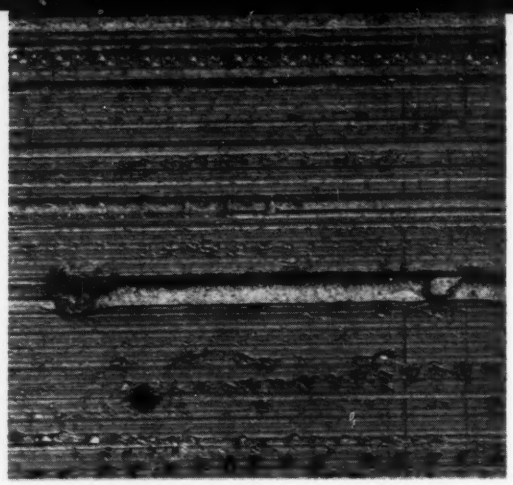


Figure 6 —Pitting due to foreign particles in a tin base babbitt sleeve bearing, 15x
(Arrow shows direction of motion of journal)

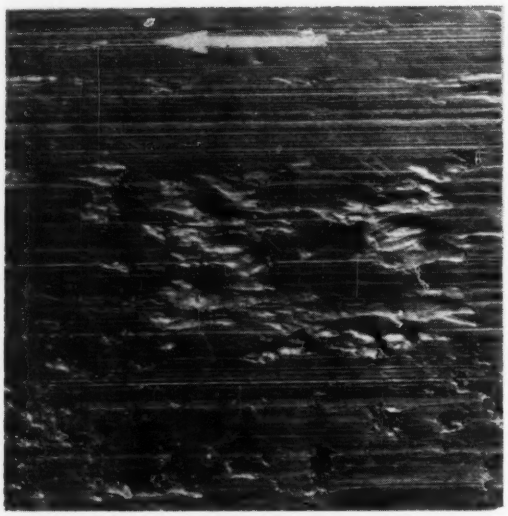


Figure 7 —Electrical pitting followed by wiping in a tin base babbitt sleeve bearing, 15x
(Arrow shows direction of motion of journal)

Figure 8 —Electrical pitting on the journal which operated against the bearing in Figure 7, 15x

Electrical pits in ball and roller bearings may produce a wide variety of periodic patterns, a discussion of which is beyond the scope of the present paper. Those wishing to study the matter further will find a detailed treatment in the paper by Waip (1).

SOURCES OF BEARING CURRENTS

Potential Applied to Shaft

The most obvious source of bearing currents is, of course, the case where a potential is intentionally or accidentally applied to the shaft and current flows through the bearings or other contacting parts to ground. This case is illustrated diagrammatically in Figure 9A. The corresponding electrical circuit is shown in Figure 10A.

Dissymmetry Effect

Even though a potential is not directly applied to a shaft, bearing currents may arise through induced effects. This may occur in various types of electrical machines. A common case is the dissymmetry effect. While the characteristics (i.e., frequency and wave form) of the bearing current which is produced by this effect is influenced by the rotor and stator arrangement of the machine, the principle by which the current is generated can be illustrated diagrammatically by Figure 9B. This figure shows a two pole alternator with north and south pole as indicated and with a stator comprised of two semi-circular sections. If the machine could be perfectly constructed so that the reluctance of the magnetic circuit was uniform around the periphery of the stator, no bearing currents would be generated. If, however, there are dissymmetries in the magnetic circuit, as there are bound to be in practical machines, bearing currents may occur. Various sources of dissymmetry may be present, such as differences in the spaces between the ends of laminations and non-symmetrical distribution of slots, but these can all be represented diagrammatically by the dissymmetry produced by differences in the size of the gaps between the two semi-circular sections of a stator, as in Figure 9B.

Bearing currents originate because each of the two fluxes ϕ_1 and ϕ_2 in Figure 9B varies in value during each revolution of the shaft. Since flux ϕ_1, for example, must flow through either the small gap or the large gap, but never both gaps simultaneously, the magnitude of ϕ_1 will rise and fall depending upon the position of the shaft. As ϕ_1 increases and decreases, it cuts any conducting material which may be present, such as the imaginary conductor MN, causing an alternating emf to be set up between M and N. It so happens that the emf generated by the change in the flux ϕ_2 reinforces that generated by the change in the flux ϕ_1. This puts an alternating potential between the extremities of the shaft and tries to set up a current which flows out through one bearing and in through the other, as indicated in Figures 9B and 10B.

Shaft Magnetization Effect

Another source of bearing current which is sometimes found in electrical machines is the shaft magnetization effect. This is due to any unbalanced ampere-turns which may surround the shaft. Such turns cause the shaft to become magnetized and set up a flux which flows out one bearing, through the frame of the machine, and in through the other bearing as shown in Figure 9C. Since each axial element of the shaft within the confines of each bearing such as MN is a conductor which cuts the flux as shaft rotates, a potential difference is set up from M to N and from P to Q. This tends to produced a bearing current which flows from the shaft to one end of the bearing, axially along the bearing and back from the other end of the bearing to the shaft, as shown in Figures 9C and 10C.

Electrostatic Effect

A fourth source of bearing current is the electrostatic effect. In this effect, charges build up on the shaft, which is insulated by the oil film, until the potential is high enough to pierce the film. When this occurs, the charge is dissipated through the bearing causing a momentary flow of current. If the source of the charge is maintained, a process of alternate charging and discharging will continue indefinitely. The various methods by which electrostatic charges can be built up are shown in Figure 9D and the corresponding electrical circuit shown in Figure 10D.

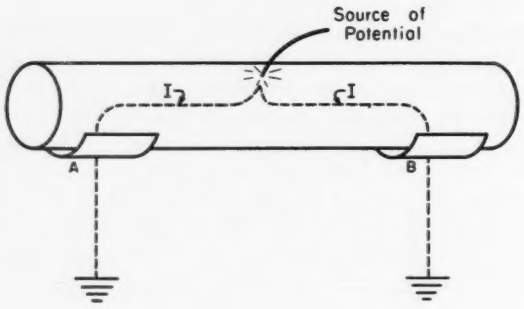
While it is not within the scope of this paper to discuss in detail the mechanism by which electrostatic charges are generated, some of the important sources of such charges will be considered.

1. *Potentials Developed by Impinging Particles*

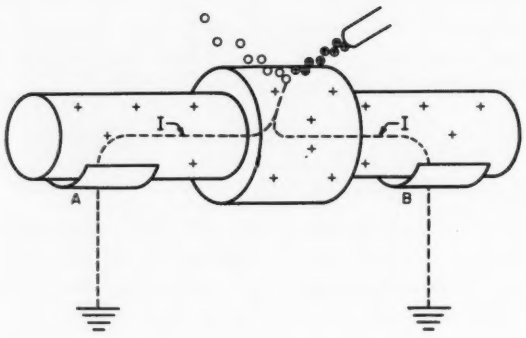
Under equilibrium conditions, each particle of a finely divided material has equal numbers of + and — charges and is therefore electrically neutral. When a stream of such neutral particles strikes an object under proper conditions, a portion of them rebound charged, some + and some —, each leaving charges of the opposite sign on the object which has been struck. The number of particles which become charged, the relative amounts of + and — charges in the stream and the distribution of the charges in the stream depend upon the properties of the materials involved and upon the conditions under which impact takes place.

Particles charged in the above manner will give up their charge to any surface with which they subsequently come in contact. If the particles are not uniformly distributed in the stream and if the surface is so located that it comes in contact with more + charges than — charges, for example, such a surface will become positively charged.

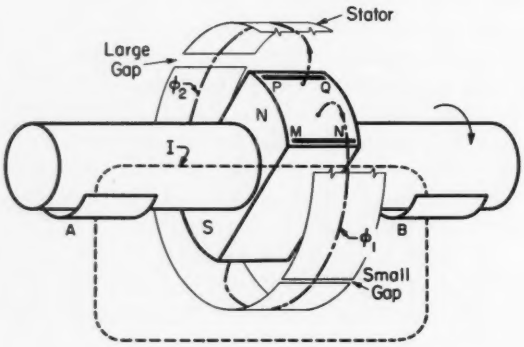
Machine parts sometimes become charged either by the process of charging neutral particles or by the process of contacting which are already charged. These charges occasionally are dissipated through the



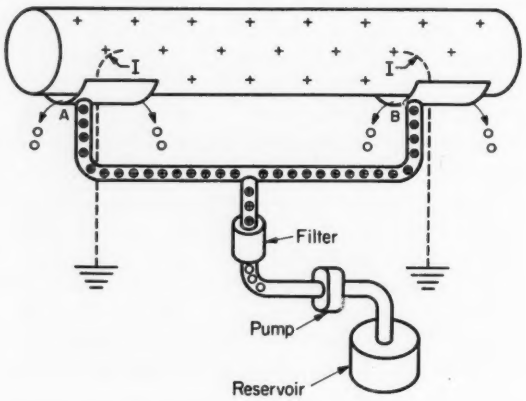
A - Potential Applied to Shaft



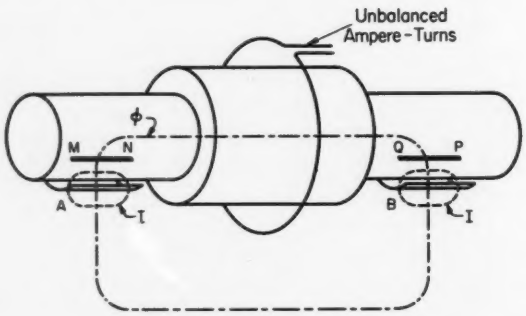
D-1 - Electrostatic Effect - potential developed by impinging particles



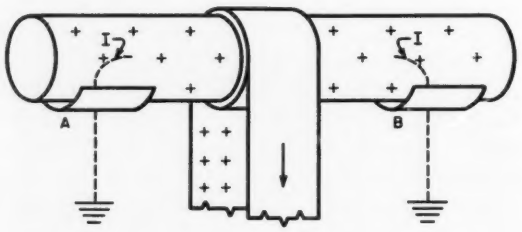
B - Dissymmetry Effect



D-2 - Electrostatic Effect - potential developed by charged lubricant



C - Shaft Magnetization Effect



D-3 - Electrostatic Effect - potential developed by charged belt

Figure 9 —Principal sources of bearing current

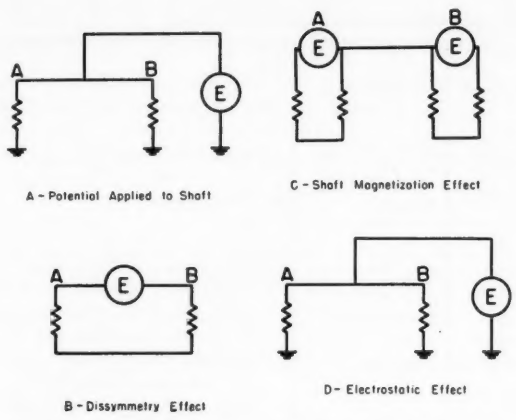


Figure 10—Corresponding electrical circuits of cases shown in Figure 9

bearings. Some of the more common cases are charges that result from moisture particles in wet steam and from dust particles. These are illustrated diagrammatically in Figure 9D-1.

2. *Potentials Developed by Charged Lubricant*

Since most lubricants are relatively poor conductors, their individual molecules behave electrically in a manner similar to the particles of a finely divided material. Thus, passing a lubricant through certain types of filters with small passages results in the molecules of the lubricant becoming charged. Since the lubricant is essentially a non-conducting medium, some of the molecules may remain charged even after passing through a considerable length of grounded pipe. Charges transported in this manner may be deposited on the journal as shown diagrammatically in Figure 9D-2 or may be also deposited on the bearing if the latter is insulated. When the potential becomes high enough, the charge may be dissipated through the oil film.

3. *Potentials Developed by Charged Belts*

Belts driving machines may sometimes be the source of electrostatic potential. Since belts usually are poor conductors, charges originating at the point where the belt leaves one pulley may be carried on the surface of the belt and be deposited upon the other pulley. If the conditions at both pulleys are the same, the rate at which the charge is being deposited at each pulley will be equal to the rate at which the charge is being taken away. However, if the conditions are different and if the shaft is insulated by an oil film, a charge may build up on the shaft. The charge so collected may be dissipated through the bearings. This is shown diagrammatically in Figure 9D-3.

CHECKING FOR POSSIBILITY OF BEARING CURRENTS

In order for bearing currents to flow, it is, of course, necessary to have a potential difference between the journal and the bearing. The tendency for the formation of current in a bearing can, therefore, be detected by measuring the magnitude of the potential difference. Whether a current will flow under a given potential difference will depend on the thickness and resistivity of the oil film. Since both the film-thickness and the resistivity vary between machines and change with operating conditions in any specific machine, hard and fast limits for allowable potentials cannot be set. Values which have been found to be generally satisfactory in practice can, however, be given.

Due to the variety of conditions which may produce bearing currents, no single method of measuring potentials is suitable in all cases. The best location for taking the measurements is indicated in Table 1.

The difference between the types of effects involved also prescribes different types of measuring instruments. Voltmeters having resistances of the order of 1000 ohms per volt are usually satisfactory for measuring most potentials except those due to electrostatic effects. For electrostatic potentials either an electronic or an electrostatic voltmeter should be used.

Since very small potentials may, under certain conditions, cause detectable damage due to bearing currents, setting a value for an allowable limit on potential is a matter of acceptability. In measuring the potential between the journal and the bearing, it has been found that a limit of 100 mv. has provided a satisfactory criterion for ordinary electrical apparatus. Since ball and roller bearings are usually more susceptable to damage from bearing currents, the limit for such bearings is lower than for journal bearings. A value of 75 mv. for such bearings appears to be satisfactory.

In the case of the dissymmetry effect, measuring the potential between the shaft and one bearing may be unreliable. This is because both bearings are in series with the generated emf and a temporary large resistance in the one bearing may make the potential across the other bearing negligible. The most reliable method is to measure the potential between the extremities of the shaft, and it has been found that a limit of 300 mv. provides a satisfactory criterion for measurements taken in this manner on ordinary electrical apparatus. The corresponding value for ball and roller bearings is 100 mv.

Since electrostatic effects are greatly influenced by humidity and by surface conditions, the measurement of electrostatic potential is apt to be extremely erratic. Thus the absence of electrostatic potential at the time a set of measurements is taken does not necessarily mean that such potentials are not present under other conditions. Generally speaking, the usual sources of electrostatic potentials ordinarily do not produce sustained currents of large magnitude. However, the intermittent charging and discharging, if continued for a sufficient period of time, can produce enough bearing damage to cause failure.

TABLE 1. PRINCIPAL SOURCES OF BEARING CURRENT AND METHODS OF CURRENT CONTROL

TYPE (SEE FIG. 9)	SOURCE OF BEARING CURRENT	LOCATION OF POTENTIAL DIFFERENCES	TYPE OF CURRENT	METHOD(S) OF CURRENT CONTROL
A	*Potential Applied to Shaft* Intentional or accidental application of potential to shaft.	Between shaft and each bearing.	AC or DC depending upon source.	a) Insulate all bearings or b) Ground shaft.
B	*Dissymmetry Effect* Variation of flux with angular position of shaft due to magnetic dissymmetry in machine.	a) Between extremities of shaft. b) Between each bearing and the shaft. (Checking for the possibility of this type of bearing currents by measuring potential difference between the shaft and one bearing not always reliable, see text. Better to check between extremities of shaft.)	AC, Frequency depending upon construction and speed of machine.	a) Insulate one bearing. If one bearing of a machine generating bearing currents is insulated and if the shaft on that end of the machine is metallically connected to the shafts of other machines, all bearings of the other machines should be insulated. or b) Ground *both* ends of shaft.
C	*Shaft Magnetization Effect* (Also referred to as Homopolar Effect) Unbalanced DC or AC ampere-turns encircling shaft causing axial magnetization of shaft.	a) Between points on the shaft located at opposite ends of each bearing. b) Between each end of each bearing and its journal.	DC or AC depending upon frequency in ampere turns.	a) Balance ampere turns by addition of neutralizing coil. or b) Increase reluctance of magnetic circuit by substituting non-magnetic material for magnetic material in bearing support. or c) Ground *both* ends of *each* journal.
D	*Electrostatic Effect*			
	1) Potential developed by impinging particles	Between shaft and each bearing.	DC, Measurements apt to be erratic—see text.	a) Insulate all bearings for high voltage. or b) Ground shaft.
	2) Potential developed by charged lubricant	Between shaft and each bearing.	DC, Measurements apt to be erratic—see text.	Ground shaft and all bearings.
	3) Potential developed by charged belt	Between shaft and each bearing.	DC, Measurements apt to be erratic—see text.	a) Insulate all bearings for high voltage. or b) Ground shaft.

The erratic nature of electrostatic potentials makes it difficult to set practical limits for satisfactory operation. It is known that peak voltages as high as 20 volts can produce bearing damage. Reducing the voltage to the order of one volt by some form of grounding device ordinarily eliminates the trouble.

METHODS OF ELIMINATING OR REDUCING DAMAGE DUE TO BEARING CURRENTS

Eliminating Source

It is, of course, obvious that one method of eliminating bearing currents is to remove the source. This solution may require drastic redesign of the apparatus in question which may not be practical and under some conditions may not be possible. Since it is not the purpose of this paper to deal with matters of design, the methods recommended are corrective measures which may be applied to existing apparatus. The methods used depend upon the cause of the current and will be found listed in the last column of Table 1.

Insulating Machine Parts

Where the table calls for insulating a bearing, all connections to the bearing, such as oil lines, etc., should be insulated so that no metallic contact exists between the bearing and its support or any surrounding conductors.

Grounding Shaft

When the table calls for grounding the shaft, the cause of the current must be taken into account. Thus, a relatively simple brush arrangement may be adequate to lead-off and prevent the accumulation of an electrostatic potential. In the case of Type B and Type C currents, however, one is dealing with low

voltages and high currents. Thus, a brush with a high contact resistance will be ineffective. For these purposes brushes with low contact resistance and with ample capacity should be used.

Modifying Machine Design

The table shows two methods of elimination or reduction for Type C currents that may be used instead of grounding or that may be used to simplify the requirements for adequate grounding. Since large currents may be involved if a large number of ampere-turns are present, it may be desirable to attempt to reduce the effect by introducing neutralizing ampere-turns. If this method is not practical, increasing the reluctance of the magnetic circuit through the bearing supports and frame by the introduction of non-magnetic material may be possible.

ADDITIONAL METHODS OF REDUCING DAMAGE

In the case of electrostatic effects, any method which will bleed off the charge as it is formed will prevent the build up of dangerous potentials. Rendering the oil more conducting by the addition of additives or ionizing the surrounding atmosphere to conduct the charge have both been suggested as methods of reducing the damage due to electrostatic currents. Neither of these methods is widely used at present.

A method of reducing bearing damage that may be used in certain cases should not be overlooked. This method is based upon the fact that the wear due to electrical pitting depends upon the film thickness as well as the voltage. This is shown diagrammatically in Figure 11. It will be seen that for every voltage such as E, there is a maximum wear-rate, point B, which occurs at some particular value of the film-thickness. If a bearing is operating in the vicinity of point B, reducing the film-thickness to the neighborhood of point E or increasing the film-thickness to the neighborhood of point A (or beyond) will reduce the wear rate substantially or will eliminate it completely. Any change calculated to alter the film-thickness such as varying the viscosity, changing the speed and load or altering the amount of lubricant supplied may be used, provided it is consistent with the operating requirements of the bearing. Since it may be difficult to determine in a given case whether one is operating on or near the maximum wear rate (point B), one should either make large changes in film thickness to be sure of avoiding the maximum wear region or should be prepared to cut and try until an improved condition is obtained.

SUMMARY

The above discussion has shown how the damage caused by bearing currents may be recognized. It has also shown how such currents originate and how the possibility of their presence may be detected. The methods which may be used to eliminate or reduce the currents or minimize the damage caused by them are summarized in Table 1.

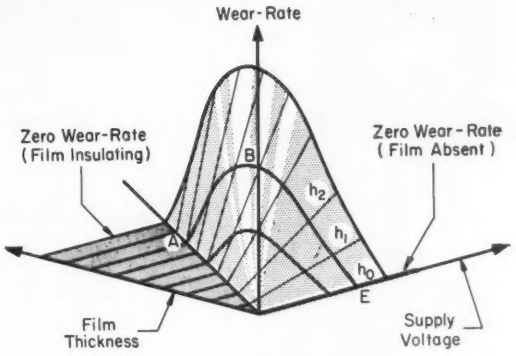


Figure 11—The influence of film-thickness and voltage on the wear-rate due to electrical pitting

ACKNOWLEDGEMENTS

The authors wish to acknowledge the helpful suggestions received from Mr. E. C. Whitney and Mr. D. B. Hoover for their helpful suggestions during the preparation of this paper.

Bibliography

With the exception of reference (1), the text makes no specific reference to prior literature on the subject of bearing currents. The following references are listed for those who may wish to study the matter at greater length.

(1) Walp, H. O., "Interpreting Service Damage in Rolling Type Bearings." ASLE Publication, 1953, pp. 20-22.

(2) Alger, P. L. and Samson, H. W., "Shaft Currents in Electric Machines," *Transactions* A.I.E.E., February 1924, Vol. 43, pp. 235-45.

(3) Pearce, C. T., "Bearing Currents—Their Origin and Prevention," *Electrical Journal,* August 1927, Vol. 24, pp. 372-6.

(4) Riggs, L. W., "How Much Shaft Current Can a Bearing Carry Safely?" *Power,* February 1944, pp. 103-5.

(5) Hoover, D. B., "Heating and Failure of Bearings Due to Little Appreciated Causes," *Water Works and Sewerage,* October 1945, Vol. 92, No. 10, pp. 297-9.

(6) Wilcock, D. F., "Bearing Wear Caused by Electric Current," *Electrical Manufacturing,* February 1949, pp. 108-11.

(7) "Static Charges Might Cause Turbine Bearing Failures," *Power Engineering,* May 1954, Vol. 58, pp. 73-4.

(8) Gruber, J. M. and Hansen, E.F., "Electrostatic Shaft Voltage on Steam Turbine Rotors" presented at ASME, Semi-Annual Meeting, 1948, Paper 58 SA-5.

(9) Kaufman, H. N. and Boyd, J., "The Conduction of Current in Bearings," ASLE Transactions, 1959, Vol. 2, No. 1.

(10) Guest, P. G., "Static Electricity in Nature and in Industry," U. S. Dept. of Commerce, *Bulletin 368,* 1939.

(11) Silsbee, F. B., "Static Electricity," U. S. Dept. of Commerce, *Circular C438,* 1942.

ANNOUNCING...

the second BIG issue of

ASLE Transactions

Volume 1, Number 2 is now available! The second issue of the 1958 Transactions is here—filled with more informative papers—more research data—more new ideas—more reasons why every ASLE member should own a subscription!

MORE THAN

AND MEMBERS STILL SAVE 2/3 THE COST

Available to non-members from
Pergamon Press, Inc., 122 East 55th Street
New York 22, N.Y.

By ordering Transactions as a member you save two-thirds of the cost to non-members, but by ordering a subscription to two issues per year you save still more. A single issue costs you $3.00, but by subscription two issues cost only $5.00 resulting in greater savings to you.

Every company with an ASLE member should have at least one copy of ASLE Transactions in its reference library. Order a subscription for *your* company today!

ASLE
84 East Randolph Street
Chicago 1, Illinois

- ☐ Please enter my order for one copy of Vol. 1, No. 1 @ $3.00
- ☐ Please enter my order for one copy of Vol. 1, No. 2 @ $3.00
- ☐ Please enter my order for Vol. 1, No's. 1 and 2 (1958) @ $5.00
- ☐ Please enter my order for Vol. 1, No's. 1 and 2 (1959) @ $5.00

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

☐ Bill me ☐ Bill company ☐ Check enclosed

Patent Abstracts

Compiled by Ann Burchick
Aluminum Co. of America

Wax Compositions, Patent #2,846,330 (E. Berthold, H. Hoyer and G. von Rosenberg, assignors to Farbwerke Hoechst Aktiengesellschaft formerly Meister Lucius & Bruning) A wax composition comprising a homogenous mixture which contains (a) a high content of ester reaction products of at least one polyhydric alcohol and a mixture of montanic acid and at least one fatty acid having from 12 to 22 carbon atoms and (b) small proportions of calcium salts of said acids and the salts of at least one of said acids in which the cation is selected from the group consisting of zinc, magnesium, aluminum and mixtures thereof, the total metal content, calculated as free metal, not exceeding 5 percent based on the weight of the ester reaction products, the ester producing mixture of montanic acid and fatty acids being in the ratio of from 75 to 97 parts by weight of montanic acid to 25 to 3 parts by weight of fatty acid.

Method of Inhibiting the Adherence of Moist Material to Metal Surfaces Under Freezing Conditions, Patent #2,846,336 (J. P. Pardo, assignor to Sta-Vis Oil Co.) A method of inhibiting the adherence of moist material to a metal surface under freezing conditions which consists of coating the surface with a mixture of "dicyclo-toppings" and "header acids" containing a substantial proportion of each in at least one diluent selected from the class consisting of mineral spirits, naphtha, gasoline and petroleum fuel oil of not heavier No. 3 grade.

High Sealing-Strength Wax Compositions, Patent #2,846,375 (W. G. Annable, C. T. O'Malley and J. W. Walsh, assignors to The Pure Oil Co.) A petroleum-derived wax composition of high sealing strength consisting of approximately 25-45 percent by weight of final composition of refined parraffin wax, about 10-45 percent by weight of final composition of a micro-crystalline wax of about 170-180 F. melting point and about 30-50 percent by weight of final composition of petrolatum wax.

Process for Sodium Soap-Salt Thickened Lubricating Greases Containing Sodium Phosphate, Patent #2,846,391 (A. J. Morway, assignor to Esso Research & Engineering Co.) In a method of preparing a grease stable at high temperatures wherein a grease-forming mixture of rapeseed oil, sodium hydroxide and an inert mineral lubricating oil is heated after saponification and dehydration to a temperature in the range of 475 to 575 F. to cause the glycerine released by saponification and decomposition produces of the glycerine to react with said sodium hydroxide; the improved method of incorporating trisodium phosphate into said grease which comprises maintaining in the reactants an excess of said sodium hydroxide above the quantity required for saponification and reaction with the glycerine and decomposition products thereof, adding to the reaction mixture at a temperature above 450 F. before appreciably cooling the grease in the range of 0.5 to 3.0 weight percent of orthophosphoric acid, forming thereby from the acid and excess alkali trisodium phosphate in such a form that no detectable crystals of the salt exist.

Metal Soap-Salt Complexes and Lubricants Containing Same, Patent #2,846,392 (A. J. Morway and J. J. Kolfenbach, assignors to Esso Research & Engineering Co.) A lubricant comprising a major proportion of a lubricating oil and in the range of 0.5 to 30 wt. percent of a complex prepared at a temperature in the range of 450 to 550 F., said complex consisting of an alkaline earth metal soap of high molecular weight organic acids and calcium acetate, said acids containing at least 20 wt. percent of a carboxylic acid having in the range of 12 to 30 carbon atoms per molecule and the molar ratio of acetate to soap being in the range of 7:1 to 45:1.

Heavy Duty Soluble Oil Composition, Patent #2,846,393 (G. R. Cook, W. W. Cortiss and A. A. Manteuffel, assignors to the Pure Oil Co.) A heavy duty soluble oil blend consisting essentially of the following ingredients in weight percent:

Sodium mahogany sulfonate	15.0-30.0
Potassium resinate	15.0- 0.0
Mineral lubricating oil	20.0-55.0
Potassium hydroxide	0.01- 0.5
Hexylene glycol	2.5- 3.5
Sulfurized alkyl ester of C_{16}-C_{18} animal fatty acids containing about 15 to 22 weight percent sulfur	20.0-30.0
Water	0.01- 0.5

said composition having the postassium hydroxide content adjusted to give the finished blend an acid number (1948 method) of about 0.50 to 2.0, and said sulfurnized alkyl esters of C_{16}-C_{18} animal fatty acids being prepared by reaction of said esters with sulfur at a temperature of about 332 to 338 F. for about five hours whereby at least 15 weight percent and no more than about 22 weight percent of sulfur is combined therewith.

Rheopectic Grease Composition, Patent #2,846,394 (L. C. Brunstrum and H. J. Liehe, assignors to Standard Oil Co.) A lubricant composition which is fluid as produced in the unworked state and which sets up to grease consistency on mechanical working which essentially comprises a mineral oil base containing about 1 to 3½ percent by weight of a lithium hydroxy stearate and which is characterized by a soap particle size of about 0.1 to 0.7 micron in length and a multi-particle soap agglomerate-in-oil structure in the unworked state, said soap particle size and soap particle-oil structure formed by chilling such a composition from the melted soap state to about 100 to 150 F., homogenizing, reheating the homogenized composition to 150 to 250 F. and diluting to such a soap content.

Conversion of Wax Into Oil, Patent #2,847,358 (J. D. Kemp and R. P. Sieg, assignors to California Research Corp.) The process of producing oil from a hydrocarbon wax, which comprises passing said hydrocarbon wax in the liquid phase and at a temperature between about 600 and 800 F., through a catalyst comprising activated alumina on which is deposited from 0.1 to 10 percent by

weight, in terms of the metal component thereof, of at least one compound selected from the group consisting of the oxides of vanadium and tungsten, together with at least one metal oxide selected from the group consisting of molybdenum oxide, cobalt oxide and nickel oxide.

Lubricating Composition Containing Surface-Esterified Siliceous Solid and Organophilic Clay, Patent #2,847,380 (J. L. Zakin, assignor to Socony Mobil Oil Co., Inc.) A grease composition consisting essentially of an oleaginous lubricant liquid and a sufficient amount to thicken said liquid to a grease consistency of a thickening agent consisting essentially of a mixture of an organophilic bentonite in which the exchangeable inorganic cation has been replaced by an organic ammonium base having a carbon chain of at least 10 carbon atoms and an organophilic estersil comprising a supercolloidal substrate coated with—OR groups, the substrate having a surface of silica and having a specific surface area of from 25 to 900 square meters per gram, the coating of—OR groups being chemically bound to said silica, R being a hydrocarbon radical of from two to 18 carbon atoms, wherein the carbon atom attached to oxygen is also attached to hydrogen in which the weight ratio of said bentonite to said estersil is between about 3:1 to about 1:3.

Anhydrous Calcium-Base Grease, Patent #2,847,381 (T. W. Martinek, assignor to The Pure Oil Co.) An anhydrous calcium soap grease comprising viscous mineral oil and a gelation agent consisting essentially of calcium soaps of mixed acids from group (1) saturated, hydroxy fatty acids having 12-24 carbon atoms, and group (2) saturated, non-hydroxy fatty acids having 20-24 carbon atoms in the molecule and differing in the number of carbon atoms by at least 2 from the number of carbon atoms in the group (1) acid, the group (1) acid constituting approximately 25-75 percent by weight of the mixed acids of said calcium soaps, and the group (2) acid constituting approximately 75-25 percent by weight of the mixed acids of said calcium soaps, the gelation agent being present in a sufficient amount to produce a gelled grease structure, and approximately 0.5-15 percent by weight of final composition of a calcium salt of an aliphatic monocarboxylic acid having 1 to 8 carbon atoms.

Procedure for Manufacture of Lithium Grease, Patent #2,847,382 (M. E. Erwin, L. U. Franklin and J. C. Gebhart, assignors to Gulf Oil Corp.) A method of preparing a lithium base grease which comprising heating a mixture comprising a fatty material, a lithium compound capable of saponifying therewith, an oil and about 0.6 to about 3.0 percent by weight of water in a closed container until a pressure of about 30 to about 90 pounds per square inch is reached, venting the vapors formed therein from said container begining at said pressure and progressively reducing the pressure therein while continuing to heat the same, continuing such heating until the contents of said container are substantially simultaneously at a temperature of about 360 to about 420 F. and about atmospheric pressure, and thereafter adding to the resulting mixture obtained additional oil to produce the desired grade of grease.

Synthetic Diester Lubricating Oils, Patent #2,847,383 (R. S. Airs, P. J. Garner, J. Hartley, and J. D. Shimmin, assignors to Shell Development Co.) A synthetic lubricating oil prepared by a process comprising heating a mixture of a substantial amount of each of at least two normally liquid diesters of at least one saturated aliphatic dicarboxylic acid in which the carboxyl radicals are separated by a chain of from about 4 to about 12 carbon atoms and alkanols of from about 4 to about 20 carbon atoms, said mixture containing not less than 5 parts of each diester per 100 parts by weight of said mixture, with an alkali metal to a temperature above the melting point of said alkali metal and below the temperature at which the mixture of diesters decomposes.

Gloss Stable Paraffin Wax Compositions, Patent #2,848,385 (K. G. Arabian and N. E. Duncan, assignors to Shell Development Co.) A petroleum wax product comprising a refined normally light-stable gloss-unstable crystalline paraffin petroleum wax and an extract derived from the extraction of a residual petroleum lubricating oil with a selective aromatics extractant, said extract having a viscosity of 400-900 SSU at 210 F. and being present in said product in an amount sufficient to impart thereto substantially improved gloss stability.

GUIDE TO AVAILABLE PUBLICATIONS

INDUSTRIAL DERMATOSES—PROTECTION PREVENTION AND TREATMENT
Medical practitioners, chemists and lubrication engineers examine use and handling of cutting oils, lubricants, and solvents and discuss protective measures in terms of ointments, housekeeping, and prevention of bacterial decomposition. $1.00. Foreign $2.00.

INTERPRETING SERVICE DAMAGE IN ROLLING TYPE BEARINGS
Manual on ball and roller bearing damage includes drawings, tables and photos to aid in classifying and identifying causes of bearing damage. $1.00. Foreign $2.00.

A SURVEY OF JOURNAL BEARING LITERATURE
Comprehensive picture of all literature dealing with journal bearing analysis, design, performance and maintenance. Compiled and written by Dudley D. Fuller, recognized authority on bearing design and lubrication. $15.00.

PETROLEUM-TYPE HYDRAULIC FLUIDS
Second in monograph series covers Hydraulic Oil Specifications and Service Properties, Viscosity, Viscosity Index, Demulsibility, Oxidation Stability, Lubricating Value, Rust and Corrosion Preventive Qualities. $1.00. Foreign $2.00.

ASLE DEPT. PUB. 1
84 E. RANDOLPH
CHICAGO 1, ILL.
Please send me

☐ Industrial Dermotoses _____copies
☐ Interpreting Service Damage _____copies
☐ Survey of Journal Bearing Literature _____copies
☐ Petroleum-Type Hydraulic Fluids _____copies

Enclosed please find $_____ (check) (money order)
My name _____
Address _____
City _____ Zone _____ State _____

Lubrication Abstracts

Edited by W. E. Campbell

"Tool Steel Bows to Deep Drawing," P. M. Unterweiser, *Iron Age.* **v 182, n 12, 1958, pp. 83-85.**
Through the reverse draw method, which is described by the diagram, it has been established that it is now possible to deep draw tool steel. The article covers the step by step process with mention of the various applications of special lubricants required. (*Abstracted by Morton Parker*)

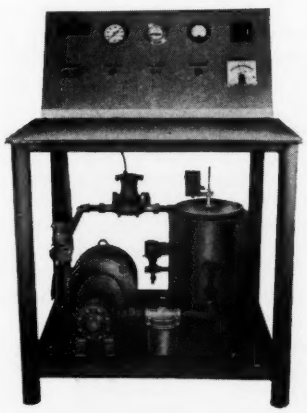
"Installation of Coolant Cleaning Equipment," third in series, Arthur L. Wilson (Barnes Drill Company). *Grinding and Finishing* **v 4, n 1, 1958, pp. 30-34.**
The importance of proper installation of coolant cleaning equipment is pointed out. Advantages and limitations are given on full flow, bypass, combination full flow bypass, and batch type installations. Engineering assistance from suppliers of filtration equipment usually insures proper installation and maximum operating efficiency. (*Abstracted by E. W. Hitchcock*)

"Recommended Methods of Cleaning Coolant on Grinding and Finishing Machines," Arthur L. Wilson (Barnes Drill Company). *Grinding and Finishing* **v 4, n 2, 1958, pp.26-29.**
A summary of various methods for cleaning coolant on finishing machines is presented. The discussion is accompanied by a table giving the particle size of swarf from different finishing operations and also a table recommending suitable methods for solids removal. A glossary of coolant cleaning terms is also included. (*Abstracted by E. W. Hitchcock*)

"Gun Drilling—Feeds, Speeds, and Coolants," (Madison Industries, Inc., Muskegon, Michigan.) *The Tool Engineer* **v 41, n 3, pp. 123-4.**
Reference is made to coolants for use with gun drilling. Emphasis is placed on proper volume of coolant, sulfur-base chlorinated cutting oil. One table is included which shows required volume of coolant for drill size and depth of cut. A second table gives viscosity and pressure at which coolant should be applied for various work materials. (*Abstracted by E. W. Hitchcock*)

"Copper-Lead Bearing Corrosion Inhibition in Diesel Service" by J. R. Thomas (California Research Corp., Richmond, Cal.), O. L. Harle, W. L. Richardson and L. O. Bowman. *Indust. & Eng. Chem.,* **v. 49, No. 10, 1957, pp. 1703-8.**
Results of a fundamental investigation of corrosion under conditions similar to those prevailing in diesel engines are given. It is shown that oxygen, rather than peroxides, is the principal oxidizing agent acting on lead. Inhibitors should function by reducing the oxidation rate as well as the yield of corrosive products. The latter begin aggressive attack when the pH of the particular detergent oil employed drops below 5.5. Formation of a protective film is another mode of inhibitor action, and experiments show how elemental sulfur reacts with lead oxide, not metallic lead, to form this film. However, the physical nature of such films must be evaluated to establish their value under dynamic conditions. (*Abstracted by M. L. Smith*)

"Experiments on the Friction and Endurance of Various Surface Treatments Lubricated with Molybdenum Disulfide" by A. A. Milne (Mech. Eng. Res. Lab., D.S.I.R., Thorntonhall, Glasgow). *Wear,* **v. 1. No. 2, 1957, p. 92-103.**
Friction and endurance tests show that, when applying molybdenum disulfide by means of water or toluene dispersions, a paste, or in a bonded syrup, superior results are obtained when mild steel surfaces are first given commercial phosphate or sulfide treatments (*Abstracted by M. L. Smith*)



Here's what the

RAC HYDRAULIC FLUID TEST

tells you about your hydraulic fluids

The RAC Hydraulic Fluid Test measures wear and indicates oxidation characteristics by viscosity, sludging and acid constituents. Rusting of the pump and system parts, color and many other factors are revealed.

This is a functional test for evaluation and selection of hydraulic fluids.

The RAC HYDRAULIC FLUID TEST is a complete unit, ready for operation. Its overall dimensions are 36″ x 36″ x 52″ to top of panel. The test runs continuously for 1000 hours at controlled temperatures and pressures.

Various models and styles are available—Send for literature.

RESEARCH APPLIANCE COMPANY

Box 307 ALLISON PARK, PA.

Publishers Representatives
Eastern Region

ASLE
84 E. Randolph Street
Chicago 1, Illinois
DEarborn 2-1298

Central Region

DWIGHT EARLY & SONS
100 N. LaSalle St.
Chicago 2, Ill.
CEntral 6-2184

Western Region (15 States)

McDONALD-THOMPSON
San Francisco 5, Calif.
625 Market Street
YUkon 6-0647
Los Angeles 5, Calif.
3727 W. Sixth Street
DUnkirk 7-5391
Seattle 4, Washington
1008 Western Avenue
ELliot 3766
Denver 2, Colorado
Colorado Nat'l Bank Bldg.
KEystone 4-4669
Houston 6, Texas
3217 Montrose Blvd.
JA 9-6711
Tulsa 4, Oklahoma
2020 South Utica
RIverside 3-1981

Metals Course Set

ASLE's Boston section is sponsoring a course on "Metal Cutting and Grinding" to be held on six consecutive Monday evenings from February 9 through March 16, 1959 at the Massachusetts Institute of Technology.

Cost of the course will be $20 for nonmembers and $10 for members. This fee includes attendance at dinner and regular monthly meeting of the Boston section on Monday, March 16 at the M.I.T. Faculty Club. R. W. Tappin, Morgan Construction Co., is chairman of the Education Committee in charge of the course.

ADVERTISERS INDEX

Acheson Colloids Corp. 5
Alemite Div., Stewart Warner Corp. ..... —
Alpha Molykote Corp. 3
Atlantic Refining Co., The ..... —
Baroid Div., National Lead Co. 16
Brooks Oil Co. ..... —
Cities Service Oil Co. 12
Emery Industries, Inc. ..... —
Farval Corp., The ..... Second cover
Grafo Colloids Corp. ..... —
Hodson Corp., The ..... Fourth cover
Ironsides Co., The ..... —
Lincoln Engineering Co. ..... —
Lubriplate Div., Fiske Bros. Refining Co. 6
Manzel Div., Houdaille Industries ..... —
Morgan Construction Co. ..... —
National Seal Div., Federal Mogul-Bower Bearings Inc. 11
Norgren Co., C. A. 9
Research Appliance Co. 39
Rollway Bearing Co. ..... —
Sinclair Refining Co. ..... —
Sun Oil Co. ..... —
Trabon Engineering Corp. ..... Third cover
Tuthill Pump Co. 7

LUBE IN NEWS *(Cont. from p. 2)*

pH they have proved entirely acceptable in contact with other metals. Contamination or prolonged overheating above 150F. sometimes depletes additives and lowers pH. This can be avoided by periodic checks of the fluid during service.

Suppliers rate the fire resistance of their fluids on the basis of various flammability tests such as spraying samples through an ignition source, or pouring samples on molten metal. There is not as yet a significant degree of standardization among these tests. But Houghton has drawn several conclusions, from their own data and that published by other suppliers, which can be profitably applied by potential users:

1. Phosphate esters—excellent fire resistance in contact with hot surfaces. In direct contact with flames they flash at relatively low temperatures (470F.), but do not readily propagate flame after ignition.
2. Water-glycols—excellent fire resistance in contact with hot surfaces over 1,000F. but usually burn with low flame.
3. Water-oil emulsions—less fire-resistant than other types but still safer than petroleum oils. Valuable for lower hazard applications.

All types of fluids now on the market will increase in usage, reports Houghton. New types of water-base media will appear and new variations of non-aqueous fluids will also be developed. Additive fortification will be used to a greater extent.

As the field continues to expand, it will become imperative for supplies to consistently apply certain basic measures in order to match fluid medium to application.

1. Check every installation thoroughly before a fluid is chosen.
2. Analyze complete specifications and operating conditions of the hydraulic system. This should be done by hydraulic engineering specialists.
3. The specialist can then recommend both fluid and any modifications necessary for the system.

In this way a new degree of certainty in the specification and use of fire-resistant fluids will be achieved.

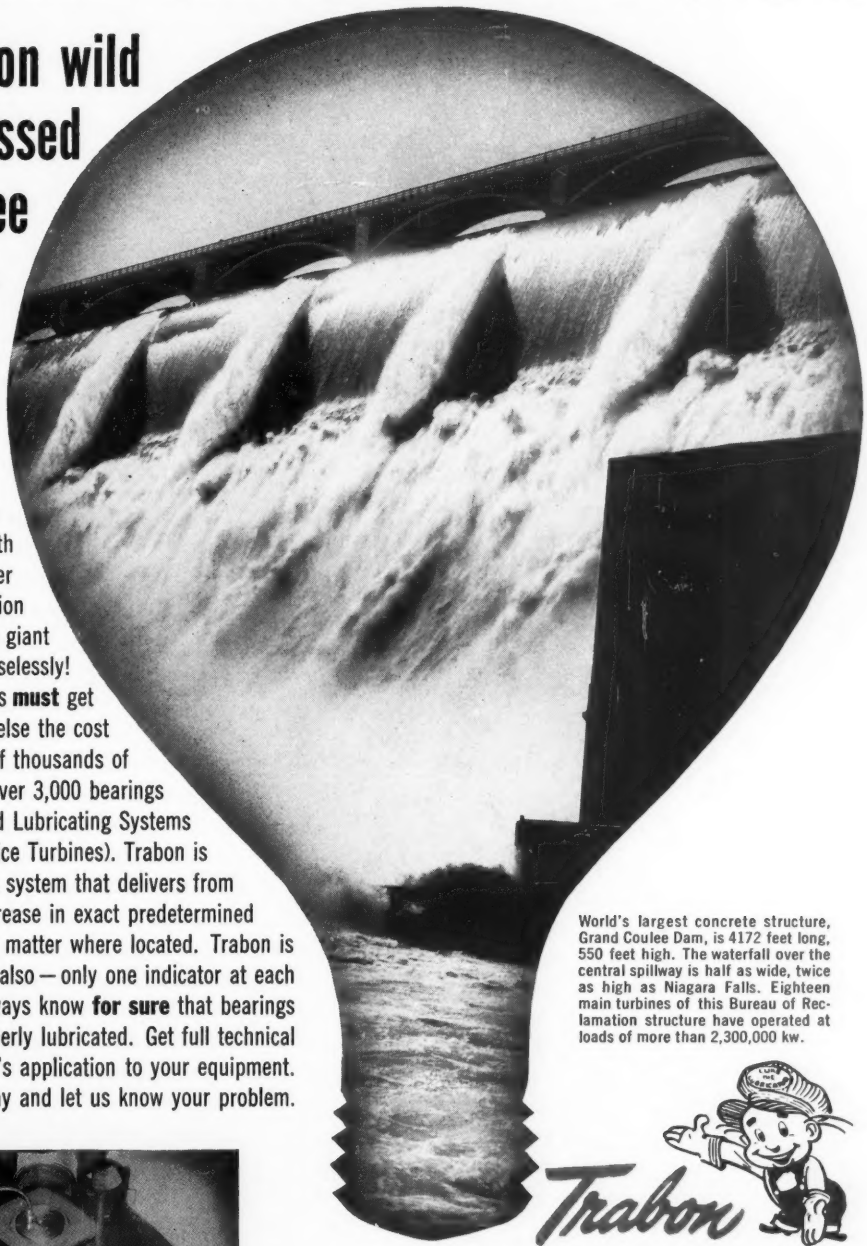
TRABON

CENTRALIZED LUBRICATING SYSTEMS

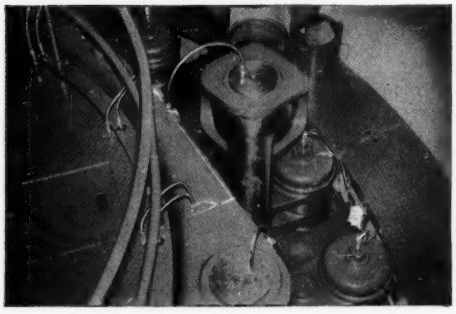
Two million wild horses harnessed at Grand Coulee

Giant turbines of world's largest dam lubricated by Trabon

The world's largest hydroelectric power plant, Grand Coulee Dam, keeps rein on the raging Columbia River with its over two million horsepower potential. **Think** of the lubrication job involved here! Eighteen giant hydraulic turbines revolving ceaselessly! Here's one place where bearings **must** get the lubricant they need or else the cost could run into the hundreds of thousands of dollars. On-the-job protecting over 3,000 bearings are 21 Trabon Centralized Lubricating Systems (including 3 Station-Service Turbines). Trabon is the economical single line system that delivers from a central location oil or grease in exact predetermined quantities to bearings no matter where located. Trabon is centralized in indication, also—only one indicator at each turbine is needed. You always know **for sure** that bearings have been properly lubricated. Get full technical details on Trabon's application to your equipment. Write today and let us know your problem.



World's largest concrete structure, Grand Coulee Dam, is 4172 feet long, 550 feet high. The waterfall over the central spillway is half as wide, twice as high as Niagara Falls. Eighteen main turbines of this Bureau of Reclamation structure have operated at loads of more than 2,300,000 kw.



"Whitened" lubricant lines and feeders show part of **one** of 21 Trabon systems helping to keep Grand Coulee Dam turbines operating. Note simplicity of Trabon installation.

Trabon

Trabon Engineering Corporation

28787 Aurora Road • Solon, Ohio

Centralized OIL AND GREASE SYSTEMS *Matic-fyd* CIRCULATING OIL SYSTEMS

Hodson's

START THE NEW YEAR RIGHT WITH LUBRICANTS OF QUALITY

All Seasons — Seasoned Lubricants

FOR

DENSOIL	Pinions, Cables, Screw Downs, Couplings, Columns, Bearings, Worm Drives, Guides.
GEARKOTE	Edging Roll Drives, Housing Roll Gears, Table Line Shaft Housing, Semi-Open Pinions.
METALICOIL	Pinions, Reduction Sets, Auxiliary Drives, Cranes, Tables, Hoists, Bridges, Locks, Industrial Trucks, Bridge and Hot Metal Car Journals.
METALICGREASE	Pinions, Mill Tables, Ore and Coal Equipment, Road Machinery, Docks, Bridges, Cranes, Locks, Cams, Guides, Slides, Screws.
NOMELT	Sintering Plants, Open Hearths, Blast Furnaces, Mills, Dogs, Dollies, Furnace Table Bearings, Pinch Rolls, Soaking Pits, Crane Columns, Coilers, Transfer Tables, Pallet Wheels, Kiln Car Journals, Coke Oven Door Latching Devices, Larry Cars, Charging Cars, Pushers, Wedges, Cartridge Boxes, Schloeman Rolls.
NONSEPARA	Sleeve Bearings, Anti-Friction Bearings, Hand or Automatic Lubricating Systems, Line Shafting, Motors, Reduction Sets, Coilers, Cranes.
METAL WORKING COMPOUNDS	Forging, Drawing, Cutting, Forming, Threading, Tapping, Extruding.

PRODUCT NAMES GEARKOTE, METALICOIL, METALICGREASE, NONSEPARA AND NOMELT ARE REGISTERED TRADE MARKS OF THE HODSON CORPORATION.

The HODSON CORPORATION

Lubrication

5301-11 WEST 66TH STREET

CHICAGO 38, ILLINOIS

1-L-59

PRINTED IN U.S.A.